

SNAP CODE :

060000

SOURCE ACTIVITY TITLE :

Solvent Use (Introduction)

1. INTRODUCTION

Emissions of NMVOCs from solvent use are commonly assessed using consumption data. This data is based on national statistics which are not necessarily categorised in the same way as SNAP codes. Nevertheless, the information can be used to develop national estimates for emissions from solvent use. The following case study is based on the work carried out in Norway to produce a solvent inventory.

Statistics Norway and the State Pollution Control Authority collaborate in the preparation of annual inventories of emissions of main pollutants to air in Norway. Inventories of NMVOC have been produced since 1973. Due to the effect NMVOCs may have on the production of photochemical oxidants, Norway has signed the UNECE convention to reduce the emissions in the mainland and economic zone south of 62N by 30 % from 1989 to 1999. Solvent use is the third most important NMVOC source in Norway, after loading of crude oil and evaporation from gasoline vehicles. It amounts to about 15 % of the total emission [1]. Thus, it is important to estimate solvent emissions by a methodology which is able to catch variations in the emissions from one year to another and that gives data for evaluating possibilities to reduce the emissions. The emissions are influenced by both changes in the solvent consumption and various environmental measures.

The concept NMVOC covers different chemical substances. Some of these have a large potential for creating photochemical oxidants, while others are of little environmental concern. Thus, a methodology for estimating NMVOC emissions should classify the various emission sources according to the photochemical oxidation potential of the emitted substances.

The aim of this work has been to develop a methodology that gives speciated emissions of NMVOC from solvent use. As sources of solvent emissions are very diffuse in Norway, a bottom up methodology will not be very useful for giving a complete emission estimate. The chosen methodology, a solvent balance, probably gives a reasonably accurate total emissions estimate, while the emission from each industrial sector is currently more uncertain. Furthermore, this methodology gives independent emissions estimates for every year of inventory.

2. METHODOLOGY

Solvent emissions may be determined by three main methodologies

Bottom up studies of emission sources and industries by means of measurements or local mass balances: This methodology is very useful for determining emissions from large sources (point sources). It will, however, not be feasible for covering more diffuse sources.

Emissions factors related to activity levels: This methodology is easy to use, but will not capture national characteristics or changes in consumption of solvents per unit activity.

Top down mass balances - solvent balances: This approach is based on statistics covering "all" consumed solvents. Hence, all sources will in principle be covered. However, information about who is actually causing the emission and the distribution between industries and other users will be less accurate.

A methodology has been developed to determine solvent emissions by a top down solvent balance. However, if accurate emission figures are available for point sources, this information is taken into account.

Most of the consumed solvents will sooner or later evaporate to air. The mass of the consumed solvents will either be imported to the country or be produced in the country. Solvents not emitted within the country are either exported, used as feedstock, incinerated or broken down in water. The solvent balance follows the flow of solvents from import and export, via transformation, to incineration or consumption (figure 1 and figure 2).

The solvent balance is based on the commodities in the statistics of foreign trade that either are pure solvents or contain solvents. Important examples are white spirits and paint based on solvents. Each of these commodities is followed through the balance - the equation is applied for each commodity and the total emission is the sum of emissions from each.

The following data are of main importance for the solvent balance:

Import and export of the various commodities as determined by Statistics Norway in collaboration with the customs authorities [2].

Production in Norway of the commodities is based on statistics from Statistics Norway as determined in annual surveys covering all main manufacturing industries [3].

Destruction of solvent waste and paint is given by official statistics on waste delivered and incinerated [4]. In addition, the State Pollution Control Authority has information about the incineration in plants with permissions to incinerate.

Solvents used as feedstock: In certain industrial processes chemical substances usually considered as solvents are used for other purposes than solvents. Important examples in Norway are styrene used for producing polystyrene and chlorinated hydrocarbons used for the manufacture of PVC. In other processes, e.g. production of paint and glue, solvents are used to produce solvent containing products. These products may either be exported or used within the country. To avoid double counting of emissions, the mass of solvents used for producing these products must be estimated and subtracted from the balance. Emissions are, in the current methodology, counted when and where the products (commodities) are used. Statistics Norway has statistics on the amount of feedstock used in industrial processes.

Figure 1. The Solvent Balance

Solvents enter the balance through *import* and *production*.

Regeneration is not counted, the commodity has already been counted as imported or produced.

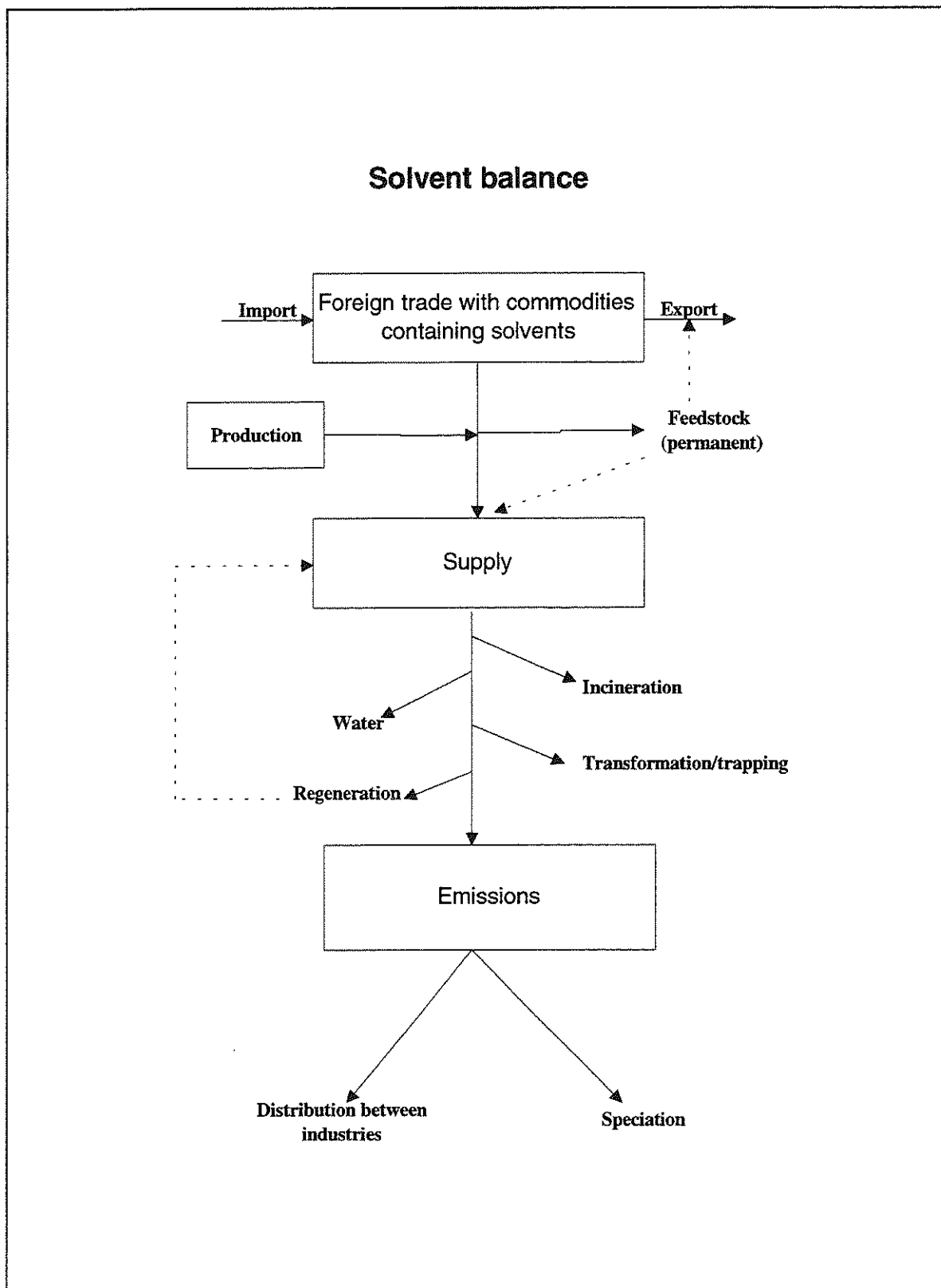
Solvents leave the balance through *export*, *destruction in water*, and *incineration*.

The difference between the supply and leave is counted as *emitted to air*.

The balance takes into account "solvents" used as *feedstock* e.g. for producing plastic.

Solvents may also be used as feedstock for producing other commodities containing solvents that may be either exported or lead to emissions in Norway. However, emissions are counted when and where the commodity is used.

Finally, the calculated emissions are distributed between industries and NMVOC group depending on the potential for creating photochemical oxidants.



Solvent content: Commodities that are not pure solvents have to be multiplied by a solvent content in order to estimate the potential emission. Solvent content has been determined from several sources. The most important source has been the Norwegian product register [5]: Here, products with possible harmful environmental or health effects are registered - the mass imported or produced, the main consumers and the chemical composition. The average solvent content is determined from the average chemical composition of the product categories. The solvent contents of the remaining commodities are, with a few exceptions, taken from investigations for other countries [6-16].

Fraction emitted: Not all solvents consumed will evaporate to air. Some will be emitted to water. The solvents emitted to water may partly evaporate to air and partly be broken down in water. For each commodity a fraction emitted to air is assumed. Generally, this fraction is higher for products that are not water soluble than for those who are.

Emissions from particular industrial processes: In plants where solvents are used as feedstock, fractions of this feedstock may evaporate to air. Emissions from these plants have been added to the solvent balance where data have been available. The emission estimates or emission factors are delivered by the State Pollution Control Authority. Furthermore, it is possible to make corrections in the model if emissions from certain plants or sectors are well known.

Emissions are roughly distributed between main *industrial sectors* utilising information about the kind of commodity, feedstock statistics from Statistics Norway, data from the Product register and data on expenditures in the National accounts.

Figure 2 Flow of solvents

The *gross consumption* of commodities containing solvents is calculated as:

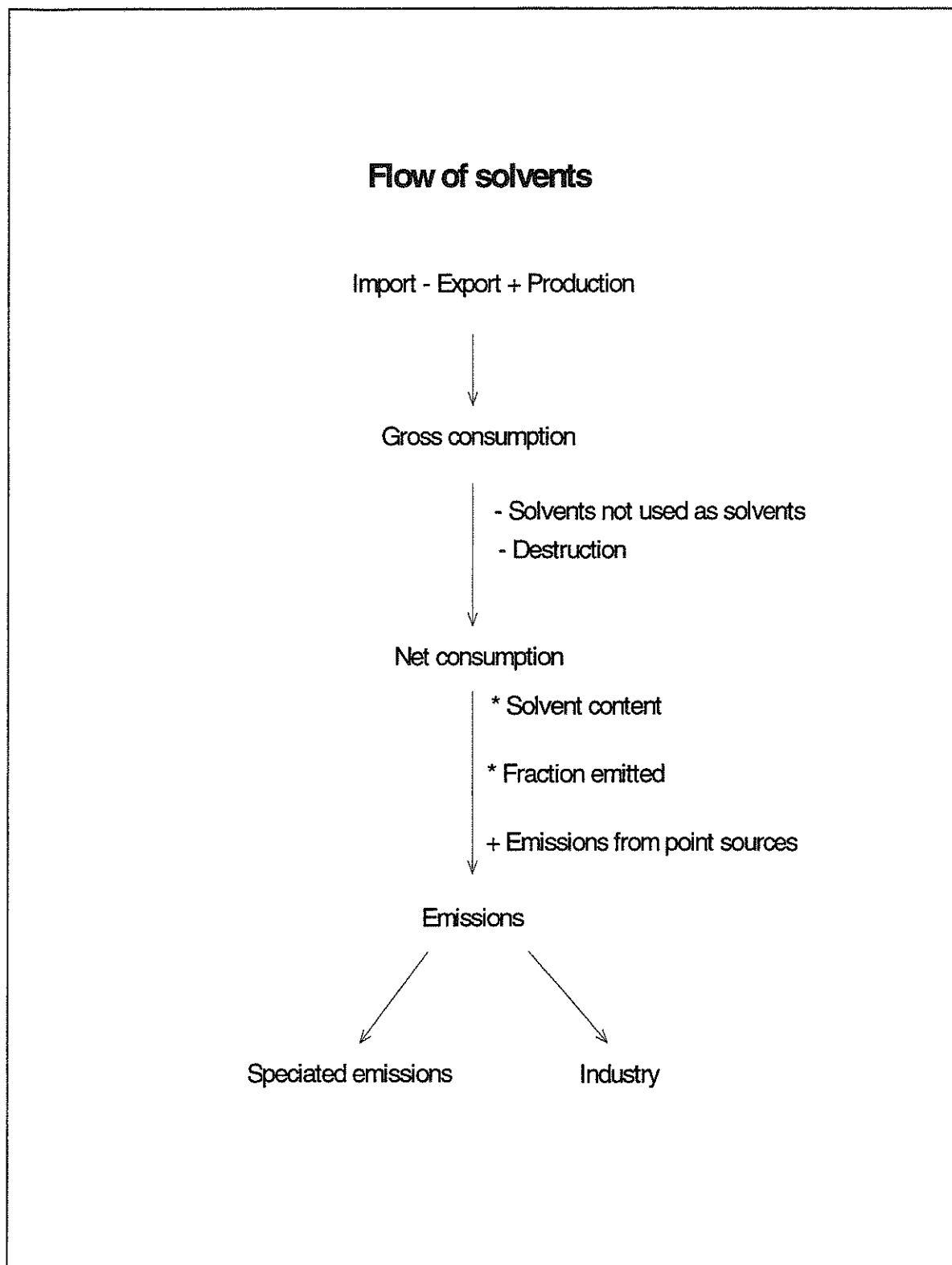
$$\textit{import} + \textit{production} - \textit{export}.$$

The net consumption is calculated as:

$$\textit{gross consumption} - \textit{feedstock} - \textit{destruction}.$$

Emissions are calculated by multiplying with *the solvent content* and *the fraction emitted to air*.

Finally emissions from *production processes* where solvents are used as feedstock or emissions are known accurately are added.



The speciation, distribution of the emissions between 19 groups of chemical substances, has been done for each commodity utilising mainly data from the Product register, but also [6-16]. These groups of NMVOCs may again be classified in three groups according to their photochemical oxidant formation potential: Very important, less important and least important.

CFCs and halons are not included in this solvent balance.

Most input data are possible to update yearly. Hence, emissions may be estimated independently for every year of inventory.

3. MAIN RESULTS

A solvent balance has been generated for the years 1976, 1981, 1986 and 1988-1992.

Which commodities are most important?

Use of paint is the most important source of solvent emissions in Norway. This source accounts for about a quarter of the total emission. Use of white spirits and other petroleum products as solvents is another source of importance. Other main sources are ink (mainly used in the printing industry), use of antifreeze and household products. Emissions from use of chlorinated solvents are 2-3 ktonnes per year only.

In 1976 this was somewhat different: Use of white spirits and other petroleum products as solvents was the most important source and use of paint the second most important source. Use of aromatic compounds as solvents and creosote in addition to use of insecticides and herbicides were also among the main sources in 1976.

How have the emissions changed and why?

The total emission in Norway was 61 ktonnes in 1976 and about 43 ktonnes in the period 1988-1992. The reduction in emission has been 18 ktonnes, or about 30 percent, in the period 1976 to 1992. However, most of this reduction was achieved between 1976 and 1988. In the period 1988 to 1992 the emissions have been relatively stable from one year to another.

The main cause of the reduced emissions in the period 1976-1988 is reduced consumption of white spirits, aromatic compounds, mixed thinners and herbicides, insecticides etc. However, the consumption of alcohols and etheralcohols as solvents, ink and household products has increased.

The consumption of most commodities has followed the economic development: an increase until late in the 1980 decade, and a decrease or stable consumption later. For other commodities the consumption has been changed due to environmental concern or regulations. The reduction in emissions from use of paint has not been very large in this period. There has been an increase in the total consumption of paint. More use of water based paint and less organic solvents in water based paints has only partly been able to offset this increase in consumption.

Is destruction of solvents important?

In recent years there has been an increase in the mass registered of solvents and solvent containing products incinerated or regenerated. Without this incineration the emissions in 1988 would have been about 5 percent higher than currently estimated.

How harmful are these emissions with respect to creation of photochemical oxidants?

In 1988 about 48 % of the emissions belonged to the group "very important" (group 1) with respect to formation of photochemical oxidants. Only 7 % belonged to the group "least important" (group 3). From 1976 to 1988 there has been a significant change. Emissions belonging to group 2 ("less important") have increased at the expense of group 1 and 3. This is due to higher emissions of alcohols and ethers (group 2) and lower emissions of white spirits and aromatic compounds (group 1) and chlorinated hydrocarbons (group 3).

Who is causing the emissions?

The construction industry is the most important emitter in Norway. A quarter of the emissions originate from this sector. About half of this is due to use of paint. The household sector contributes 16 % of the total emission. Use of typical household products followed by use of paint, white spirit and anti freeze are the main sources.

41 % of the emissions in Norway originate from the manufacturing industry. The main sectors are the graphical, furniture, mechanical and chemical industry. Use of ink, paint, and white spirits are the main emission sources in the manufacturing industry.

How credible are the results and why is the uncertainty high?

The total emission may be overestimated by 5 ktonnes and underestimated by as much as 10 ktonnes. The main reason for this high uncertainty is:

The consumption data are uncertain, whether the correct commodities are included and the quality of the statistics.

The estimated feedstock is very uncertain. This is due to rather bad statistical quality, lack of statistics for some years and lack of knowledge about how the commodities actually are used within each sector.

The mass of solvents and solvent containing products incinerated is probably underestimated.

This is, however, of minor importance for the overall uncertainty in the total emission.

The factors for solvent content of each commodity are partly taken from data for other countries than Norway. Even if the solvent content has been determined from Norwegian data, the commodities used in the current model are not necessarily the same products as those from which on the solvent contents were originally determined. This may be a major source of error.

The assumptions about the fraction emitted is probably a minor source of error for the total emission.

The changes in emissions from one year to another is better determined. The emissions by sector determined by this methodology is highly uncertain. The distribution of emissions between the VOC groups 1,2 and 3 is relatively certain.

4. CONCLUSIONS

A solvent balance is a useful tool for estimating diffuse NMVOC emissions. The uncertainty in emission estimates is high, but will probably be higher utilising other methodologies demanding the same amount of effort. We have by this approach been able to determine and explain the emissions in the period 1976-1992 in Norway. The weakness of this approach is the high uncertainty in the distribution between industrial and others sectors.

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6. RELEASE VERSION, DATE AND SOURCE

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ADDITIONAL NOTE ON SOLVENT USE

The following additional note may prove useful when preparing emission inventories from the solvent use sector.

The NMVOC emission from solvent use can be calculated using consumption (or production) statistics for several categories. The user categories which are often most suitable for this purpose are:

- paint, all applications
- industrial degreasing and dry cleaning
- glues & adhesives
- graphic arts (ink)
- rubber & plastics industry

Two user categories, which also contribute substantially, are hard to inventorise, namely:

- chemical industry (e.g. pharmaceuticals)
- household products (e.g. toiletries)

In the other group 6 chapters solvent content and/or emission factors for several user (sub)categories are given. Multiplying the user category consumption with the solvent content or emission factor gives the NMVOC emission for that user category.

When the emissions from all known user categories are calculated, the emission for the unknown user categories has to be estimated. This can be done by using the percentages that the unknown user categories contribute to the total NMVOC in countries, which have a complete inventory. For the U.K., West Germany, Italy, Sweden, France, the Netherlands and Western Europe relatively complete inventories are available (see [9], [10], [16], [15], [17], [18] and [19]); Table 4 gives the subdivision in user categories for these countries.

To provide an idea of the size of some user categories table 1 lists solvent emissions per user category reported by several industrialised countries. The table was originally made by Veldt [20] and has been updated and expanded by Bloos. The table can also be used to estimate a per capita emission for the user categories mentioned.

Table 1: Reported solvent emissions for some user categories (in kg/cap./year)

Country	year	paint	industrial degreasing	graphic arts	glues & adhesives	household products	total
Australia	1990						11.0
Austria	1987	5.3		0.60	1.45		
Canada	1985	4.8					12.7
Finland	1991	3.7	2.7 ¹	0.4	0.17	0.27	12.3
France	1985	4.8	0.84	0.47	0.26	1.1	10.4
W. Germany	1986	6.8	2.0	1.5	1.1	±2	18.8
Italy	'84-'86	4.55	0.75	0.60	1.0	0.8	12.9
Japan	1983	6.4	0.74	1.15	0.29		10.4
Netherlands	1990	4.5	0.40	0.76		1.5	10.0
Norway	<1992	4.5		0.36			7.5
Poland	1989	4.45					
Sweden	1988	4.7	1.4	0.82		2.6	12.1
U.K.	1988?	4.8	0.81	0.68	1.02	3.3	13.7
USA	1989	8.6	2.8	1.3	1.3	1.5	21.3
W. Europe	1990	5.3	1.0	0.86	0.84	1.1	14.4

1 includes industrial and dry cleaning

Table 2 gives an idea of the NMVOC profile for solvent use. All profiles are for the complete solvent use category, for profiles per user category see the relevant chapters for group 6. As for table 1, this table was originally made by Veldt [20] and updated by Bloos.

Table 2: Reported solvent emissions per substance group (wt.% of total solvent emissions)

Country	year	alkanes	aromatics	alcohols	esters	cellosolves	ketones	CHCs	other
Australia	1990	36.5	27.9	10.4	4.9	5.6	3.7	8.6	2.4
Austria	1987	29.5	11.3 ¹	18.8	8.1	4.4	16.7 ²	10.7	0.5 ³
Finland	1991	26.1	18.0	34.4	7.4	4.4	6.5	3.3	0.0
France	1985	26.1	14.6	27.5	5.6 ⁵	⁵	9.8	14.5	1.9
Germany	1986	20 ⁴	20 ⁴	15.7	9.6	4.2	8.9	15.6	6.0 ³
Italy	'84-'86	15.1	24.0	14.8	9.9	4.3	13.8	15.4	2.7
Sweden	1988	12.4	13.7	29.8	8.8	4.8	2.6	9.6	18.3 ⁶
W. Europe	1990	27.3	18.7	16.3	10.2	5.3	11.8	10.1	0.3
USA	1989	30.9	8.7	17.9	14.7 ⁵	⁵	11.1	12.8	3.8

1 toluene and xylene

2 acetone (propanone)

3 includes CFCs

4 corrected for aromatics in alkanes

5 esters include cellosolves

6 includes unknowns

Table 3, also originally by Veldt [20] and updated by Bloos, gives the NMVOC profile for the user category paint applications.

Table 3: Reported solvent emissions from paint applications per substance group (wt. %)

Country	year	alkanes	aromatics	alcohols	esters	cellosolves	ketones	ClHC	other
Finland	1991	28.3	32.1	13.1	13.1	11.4	1.8	0.2	-
France	1985	29.6	18.4	28.8	8 ¹	-	14.6	0.6	-
Germany	1986	11 ²	23 ²	17.8	17.8	11.5	10.4	6.9	1.6
Italy	'84-'86	13.4	42.1	11.5	11.5	7.7	11.5	1.5	0.8
Sweden	1988	15.6	26.4	24.0	23.6	8.4	2.0	-	-
W. Europe	1990	29.7	24.1	11.5	17.7	6.9	9.9	0.0	0.2
U.K. ³	recent	11.4	49.5	13.8	6.3	4.8	12.5	0.5	1.2
USA	1989	17.1	15.9	16.0	29.8 ¹	-	16.5	2.9	1.8

1 includes cellosolves

2 corrected for aromatics in alkanes

3 industrial paint

Table 4 lists the percentages of user categories as found in several European countries. With table 4 it is possible to estimate which percentage of the total NMVOC emission due to solvent use is covered by known user categories, in order to determine which percentage for unknown user categories should be added to provide the total NMVOC emission.

Table 4: Reported user category subdivisions in country studies

user category	Country						
	France	Germany	Italy	Netherlands	Sweden	U.K.	W. Europe
Paint	46.1	39.6	35.2	40.4	36.1	35.6	36.7
Household prod	10.6	9.2	3.5	15.5	18.5	21.6	8.2
Chem. ind.	14.0	10.8	13.7	12.4	4.7	5.5	11.8
Other solv. use	0.5	8.2	14.8	11.7	16.3	8.7	20.5
Ind. degreasing	8.1	10.8	5.8	6.4	10.5	5.8	6.9
Graphic arts	4.5	8.2	8.0	8.8	6.3	5.6	5.9
Glues & Adh.	2.5	5.8	8.0	0.4	¹	7.9	5.8
Rubber & plastic	7.5	3.5	2.3	3.5	4.3	0.9	¹
Dry cleaning	3.1	2.0	4.7	0.9	1.5	1.5	2.1
Pesticides	2.7	0.5	2.1	¹	1.4	5.3	¹
Veg. oil extr.	0.5	1.4	2.0	¹	¹	1.4	2.2
Leather	¹	¹	¹	0.2	0.5	0.3	¹

1 included in other solvent use

2 rubber industry only

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SNAP CODES :	060101
	060103
	060104
	060108

SNAP ACTIVITY TITLES :	Manufacture of Automobiles
	Construction and Buildings
	Domestic use
	Other Industrial Paint Application

1. ACTIVITIES INCLUDED

Activity 060101 "Paint application: manufacture of automobiles" refers to vehicle coating; it includes corrosion protection at point of manufacture; it does not include vehicle refinishing and underseal treatment of vehicles (SNAP code 060407).

Activity 060103 "Paint application: construction and buildings" refers to the use of paints for architectural application by construction enterprises and professional painters.

Activity 060104 "Paint application: domestic use" refers to the use of paints for architectural applications by private consumers. Other domestic solvent use should not be included. However, it is sometimes difficult to distinguish between solvents used for thinning paints and solvents used for cleaning. See chapter B648 for further guidance.

Activity 060108 "Other industrial paint application" refers to ship building, manufacture of metal articles, wood products industry, manufacture of plastic articles and vehicles refinishing.

This version (1.5) was written to cover these four activities as defined in SNAP90 (SNAP90 code 060102 has now become SNAP94 code 060108). The chapter has not yet been extended to cover explicitly the additional sub-sector activities introduced in SNAP94. However, some of the information presented will be relevant to to these new activities.

2. CONTRIBUTION TO TOTAL EMISSIONS

Table 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Manufacture of Automobiles	060101	-	-	0.6	-	0	-	-	-
Construction and Buildings	060103	-	-	1.7	-	-	-	-	-
Domestic Use	060104	-	-	0.9	-	-	-	-	-
Other Industrial Paint Applications	060108*	-	-	3.3	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

* = SNAP90 code 060102

According to OECD estimates for the year 1980, paint application accounts for 15.8% of all stationary emissions of NMVOC and 26.1% of all stationary anthropogenic emissions in the whole OECD (OECD, 1990).

Table 2: Contribution of paint application to NMVOC emissions in different OECD regions

Country, region	Contributions to stationary emissions	Contribution to stationary anthropogenic emissions
OECD Europe	18.1%	32.4%
Canada	7.6%	13.2%
USA	15.3%	24.2%
Total OECD	15.8%	26.1%

Source: OECD, 1990

3. GENERAL

3.1 Description

Surface coating is the application of decorative or protective materials in liquid or powder form to substrates. These coatings normally include general solvent type paints, varnishes, lacquers and water thinned paints. Emission of NMVOC occur in paint application operations because of evaporation of the solvent used to thin paints at the coating facilities or used for cleanup. All unrecovered solvents can be considered potential emissions. The major factor affecting these emissions is the amount of volatile matter contained in the paint. Conventional paints contain approximately 50% dry substance and 50% organic solvents. In addition, other solvents may be added to the paint to thin the coating before application. After application of coating by one a variety of methods, the surface is air or heat dried to remove the volatile solvents from the coated surface.

3.2 Definitions

Coat: any preparation which is used in a coating process and which provide a decorative, protective or other functional effect on a surface.

Coating: the laying on of a continuous layer of a preparation resulting from a single application. It does not include coating with metals by electrophoretic and chemical spraying techniques, any printing process but printing onto cans and drums. It comprises the preparation and the cleaning of the application equipment.

Paint: liquid or powder product with pigment to be applied on a surface in order to form an opaque film (or coating) with protective, decorative and/or particular technical properties.

Varnish: not pigmented product composed of binders, solvents and additives to be applied on a correctly prepared surface and able to form a strong adhesive, translucent and gloss coating with protective and technical properties.

Lacquer: a material which contains a substantial quantity of a cellulose derivative, used to give a glossy finish, especially on brass and other bright metals.

Solvent: liquid used as a carrier for the pigment and hardening agents in the. Unless otherwise stated, in this chapter solvent refers to organic liquids rather than water.

3.3 Techniques

Activity 060101. Paint application: manufacture of automobiles

Surface coating of an automobile body is a multi-step operation carried out on an assembly line conveyor system. Although finishing processes vary from plant to plant, they have some common characteristics. Major steps of such processes are: solvent wipe, phosphating treatment, application of prime coat, cutting of prime coat, application of guide coat, curing of guide coat, application of topcoat(s), curing of topcoat(s), final repair operations. It is increasingly common for cars to be finished using a base for enhanced appearance and bodywork protection. This process requires an extra coat of paint, and generally leads to higher emission rates (powder coating is currently being developed in order to avoid emission increases).

The application and curing of the prime coat, guide coat and topcoat account for 50 to 80% of the NMVOC emitted from assembly plants. Final topcoat repair, cleanup, and miscellaneous sources such as the coating of small component parts and application of sealants, accounts for the remaining 20%.

Several factors affect the mass of NMVOC emitted per vehicle from surface coating operations in the automotive industry. Among these are: NMVOC content of coatings, volume solids content of coating, area coated per vehicle, film thickness, transfer efficiency.

Activity 060103 Paint application: construction and buildings

Activity 060104 Paint application: domestic use

In the architectural uses of paints, no large differences can be identified between activity 060103 "Paint application: construction and buildings" and activity 060104 "Paint application: domestic use". In the first one (decorative trade), paint is supplied to professional decorators and used by painting contractors, local authorities, government departments, industrial and commercial companies etc. It is possible to distinguish the main following applications of paints for the whole architectural sector:

- walls, ceilings, floors in indoor applications;
- walls, floors in outdoor applications;
- wood substrates in indoor applications: floors, furniture, doors, window frames;
- wood substrates in outdoor applications: fences, garden sheds, gable boards, garden furniture, wooden chalets;
- metallic substrates in indoor applications: radiators, tanks;
- metallic substrates in outdoor applications: fences, portals, garden furniture;

For all of these cases the application techniques are the same: brushing, rolling, spraying and electrostatic spraying. In the second one (decorative retail), paint is used principally by the "do-it-yourselfer"; the only application techniques are brushing and rolling. Not all paint types are suitable in all cases.

Activity 060108 Other industrial paint application

Industrial activities other than the manufacture of automobiles contribute for 50% to total NMVOC emissions from paint application; they include construction of ships, manufacture of metal articles, wood industry, manufacture of plastic articles, vehicles refinishing. Manufacture of metal articles can be further subdivided into can coating, other metal coating, large appliance surface coating, metal furniture surface coating.

Depending on the product requirements and the material being coated, a surface may have one or more layers of coating applied. The first coat may be applied to cover surface imperfections or to assure adhesion of the coating. The intermediate coats usually provide the required colour texture of coating by one of a variety of methods such as brushing, rolling, spraying, dipping and flow coating, the surface is air and/or heat dried to remove the volatile solvents from the coated surface.

Approximately 70-80% of metal surface coating processes may be classified "enclosed processes" with the coating taking place in a contained workplace, ie a ventilated room or a paint spray booth. These are theoretically capable of being fitted with abatement equipment. In some cases, however, it would not be practical to construct an enclosure around the object to be coated, eg in "structural and corrosion protection" and "marine" sectors.

In the wood industry, wood may be colour coated, stained or varnished. The following steps can be distinguished in a painting process: sanding (on raw wood), staining, surfacing, coating and drying. Most emissions take place in the drying ovens, particularly during the flash-off period, and during the coating phase; both steps take place in closed environments, and the relevant emissions are conveyed. The majority of industries involved in the coating of wooden surfaces can contain the application and curing/drying stages of the process. However, this is not widespread practice at the present time, particularly for the drying process which is frequently carried out in ambient conditions. The application technique depends on the rollers or other machines characterized by a very high, practically total transfer efficiency. Spray coating is used in the case of non-flat or complex elements; this operation takes place in appropriate painting booths.

3.4 Emissions/Controls

The best - and in some cases the only - way to control NMVOC emissions from paint application is by prevention by altering the process in such a way that no products containing solvent have to be used, or by reformulating the product in order to minimize the solvent content (see Table 4). Where for practical reasons prevention is not (yet) possible, "add-on" or "end-of-pipe" abatement technology should be used.

Paint technology is developing rapidly: increasingly more low-solvent coatings become available as a result of intensive research. Low-solvent and solvent-free paint can be divided into several categories. Table 3 gives a brief review of alternative paints with their solvent content.

Table 3: Solvent content of alternative paints

Category	Mean solvent content (%)
Waterborne paint	< 20
Powder paint	0
High-solid paint (1 pack alkyds)	< 30
Low-solvent (1 pack radiation cure) ^a	0 - 3
Low-solvent (2 pack epoxy) ^b	< 10
Low-solvent (2 pack polyurethane paint) ^b	< 10
Conventional solvent paint	40 - 70

Source: ECE - VOC Task Force, 1990

a): setting of paint by IR or UV radiation

b): setting of paint by chemical reaction between binder (base-component) and hardener

The solvent content on application may be higher due to the use of 'thinners'. It should be noted that some types of alternative paint still contain a low percentage of solvents. This is the case for waterborne and high-solid coatings. However, the content of organic solvents in these coatings is less than 30%. Powder and solvent-free coatings do not contain organic solvents. When considering the effectiveness of changing to different coatings, it is important to consider the coverage efficiency, since this varies from paint to paint, as well as the solvent content.

Control options on exhaust air are the following:

- adsorption onto a solid surface;
- adsorption by a liquid;
- membrane separation;
- condensation;
- incineration;
- biological treatment.

Typical ranges of efficiencies for different control options are given in Table 4. More precise values can be given for each type of coating operation.

Table 4: Control efficiencies for surface coating operations

Control option	Reduction ^a (%)
Replace with waterborne coatings	60 - 95
Replace with low solvent coatings	40 - 80
Replace with powder coatings	92 - 98
Add afterburners/incinerators	95

Source: EPA, 1985. a): expressed as % of total uncontrolled emission load

Improvements in the transfer efficiency (fraction of the solids in the total consumed coating which remains in the part) decrease the amount of coating which must be used to achieve a given film thickness, reducing emissions of NMVOC to the ambient air. With brush and roller painting the loss of paint is small; however, uneven coating may lead to higher paint consumption. With spray painting, on the other hand, only part of the paint is effectively used since a large or small portion of the paint is sprayed around the products. Spray losses are

determined by the product's shape and the spray equipment used. Transfer efficiency for typical air atomized spraying ranges from 30 to 50 per cent. Electrostatic spray is most efficient for low viscosity paints. Charged paint particles are attracted to an oppositely charged surface. Spray guns, spinning discs or bell shaped atomizers can be used to atomize the paint. Typical transfer efficiencies are in the range from 60 to 95%.

'End-of-pipe' abatement technologies can be considered by introducing the control system efficiency. As this value depends both on the efficiency of the capture device and that of the control device, it must be referred to a specific coating operation; see, for instance, EPA, 1985 and A&WMA, 1992.

Activity 060101 Paint application: manufacture of automobiles

With particular reference to car coating operations, three significant actions can be taken to reduce emissions:

- i) installations of abatement equipment;
- ii) modification of the spraying process, the oven and air supply systems
- iii) formulation of coating.

With regard to item i), only two technologies have actually been proven on a large scale in commercial installations:

- adsorption onto a solid surface;
- incineration

The latter can be used either as the final step after adsorption or as a "combined" collection and destruction process.

With regard to item iii), opportunities exist for changes in coating formulations as follows:

- coating solvent content: water-borne, high solids, powder coatings;
- steel body part versus pre-coloured plastic parts.

Water-borne paints and low-solvent lines are already in use in some automobile painting lines. For special parts (eg fuel tanks, shock-absorbers) powder paints are also already in use.

The potential for reducing solvent vapour emissions from car painting processes by means of different control options is given in Table 5. The reductions achieved by each technique will depend on the order in which they are applied; the following data refers to sequential application of the control techniques in the order listed.

Table 5: Potential Reductions in NMVOC emissions from car painting processes

Control Option	Reduction(%)
Incinerators on paint ovens	6 - 7
Improved application efficiency	5- 10
Low solvent paints	28 - 39
Water based paints	<6
Application of abatement equipment on spray booths	62 - 69
Solvent management	39 - 41

Emission limit values are established by different legislations; they can be used to estimate actual emissions, as an alternative to the above mentioned approach, based on uncontrolled emission factors and control system efficiencies. Emission rates related to the vehicle used, for instance, in the French legislation, an emission standard of 0.14 kg/m² is in effect from 03.01.1987 for new plants, from 01.01.1991 for existing plants, whereas a circular dated 11.06.1987, referring to the act of 19.07.1986 establishes a figure of 0.105 kg/m² solvent emitted per car painted as the first minimum objective to be achieved within 5 years.

The following values of emission factors expressed in kg/m² have been drawn from national information and from the proposal for an EC Directive on solvent emissions.

Table 6: Emission rates in use or proposed in different legislations

Country	(kg/m ² of car body)	Date of entry into force	Notes
Germany	0.060	3/1/86 (new), 3/1/91 (exist.)	Uniform paint + lacquer ¹
	0.120	3/1/86 (new), 2/1/91 (exist)	Metallized paint + lacquer ¹
	0.035	May 91 ?	New plants
	0.045	May 91 ?	Existing plants
Italy	0.060	note 2	Existing plants
	0.120	note 2	Single application solid coat (existing plants)
	0.090	July 93	Double application or metallic coat new plants (existing plants ³)
Sweden	0.126	92	Actual average emission rate
	0.030	97/8 ⁴	
UK	0.060	93	Current legislation
EU	0.045	99?	>5000 monocoque cars per 12 months new plant
	0.060	04	>5000 monocoque cars per 12 months existing plant
	0.090	99?	<5000 monocoque cars per 12 months new plant
	0.120	04	<5000 monocoque cars per 12 months existing plant

- 1) The limit does not cover refinishing and waxing
- 2) 1992 for applications using highly toxic solvents, 1994 for applications using less toxic solvents but emitting greater than twice the guideline limit, 1997 for applications using less toxic solvents and emitting less than twice the guideline limit.
- 3) Equipped with water based paint, high efficiency electrostatic spraying, incinerators on bake ovens.
- 4) The two Swedish car companies have applied to have final implementation delayed by three years.

At present, no special regulations refer to NMVOC emissions from van, truck and bus coating processes; however, they should be significantly higher than for passenger cars given the fact that:

- the ratio between the surface coated in spray booths and the total surface (electro-coat) is substantially higher for commercial vehicles than for passenger cars;
- nearly all applications are manual, resulting in a much lower efficiency compared with automatic spraying;
- the automation of the spraying system is difficult due to the low production volume and the variation in shape of the products;
- the colour range is much wider (up to one hundred different colours), which calls for more frequent colour change operations and a large consumption of washing solvents.

The situation is the same for passenger cars with more than six seats.

Activity 060103 Paint application: construction and buildings

Activity 060104 Paint application: domestic use

In the household sector and the commercial painting sector the only means to reduce NMVOC emissions are:

- to reduce the consumption of such products;
- to change the product composition;
- to change the modes of application.

To increase the effectiveness of implementation, additional measures, such as labelling of products and economic incentives for the use of low solvent products, could be taken.

Activity 060108 Other industrial paint application

Many types of control techniques are also available to reduce NMVOC emissions from other industrial paint application operations. These control techniques normally fall under one of three categories:

- modification in paint formula
- process changes
- add-on controls

At the present time modification in paint formula is the best means to reduce solvent emissions in industrial paints. Low solvent coating may reduce NMVOC emissions by 40 to 100 per cent. However, substitutes for products currently being used may not always be commercially available or fully developed for some applications.

Process changes are:

- improvement of the application processes: electrostatic guns, heated paints;
- reduction of the ventilation air flow rate with a better ventilation control, a recirculation system for the ventilation air from the manned cabins to the unmanned zone;
- the development of the use of pre-painted metal sheets.

Add-on controls are activated carbon adsorption, thermal and catalytic incineration. These technologies may have very high technical efficiencies of 90 to more than 99 per cent, but may

only apply to a portion of the emission from the entire facility. Due to the high flow rate of the air and the low solvent content, the treatment is not economic and is technically complex.

In any wooden coating process substantial fugitive NMVOC emissions - sometimes as high as 50% of total emissions - can arise from the mixing, application and curing of coatings and also from any plant cleaning operations. Fugitive emissions can be reduced by good solvent management, low solvent coatings, highly efficient application techniques, and also by enclosing the process wherever possible so that the air can be extracted through NMVOC abatement equipment. As concerns the types of coatings, the use of high-solid paints (eg UV-cured paints) is the most promising option; powder or waterborne paints are less common, as they require high polymerization temperatures, not compatible with the wooden support. Oven and spray booths can be equipped with activated carbon systems or combustion devices (both catalytic and thermal). Activated carbons must be avoided for some dangerous and reactive solvents; combustion technologies, on the other hand, are highly efficient with low air flow rates, whereas wood products industry is characterised by very high flow rates. Considerable efforts are being made towards an improvement of transfer efficiencies (common values are 0.15 - 0.5 for automatic systems and 0.1 - 0.2 for manual systems).

Car repair activities can apply emission reduction means, which are either similar to domestic measures for smaller repair shops or similar to industrial measures for large repair shops.

4. SIMPLER METHODOLOGY

The simpler methodology is to multiply the consumption of paint by an emission factor.

An alternative methodology for activity 060101 is to combine the number of automobiles produced with an emission factor depending on the quality of the coating, the type of application systems and the control devices

Note. The activity statistics for paint use may not be easily categorised into the SNAP categories. At a simple level, it may only be possible to quote an emission for paint use as a whole.

5. DETAILED METHODOLOGY

Realistic estimates for the different coating processes can only be obtained by means of solvent usage data. Plant-wide emissions can be estimated by performing a liquid material balance in uncontrolled plants and in those where NMVOCs are recovered for re-use or sale. This technique is based on the assumption that all solvent purchased replaces NMVOCs which have been emitted. Any identifiable and quantifiable side streams should be subtracted from this total. The general formula for this is:

$$(\text{solvent purchased}) - (\text{quantifiable solvent output}) = \text{NMVOC emitted.}$$

The first term encompasses all solvent purchased including thinners, cleaning agents, and the solvent content of any pre-mixed coatings as well as any solvent directly used in coating formulation. From this total, any quantifiable solvent outputs are subtracted. These outputs may include solvent retained in the finished product, reclaimed solvent sold for use outside the plant, and solvent contained in waste streams. Reclaimed solvent which is re-used at the plant is not subtracted.

The advantages of this method are that it is based on data that are usually readily available (eg from associations of paint manufacturers and sellers), it reflects actual operations rather than theoretical steady state production and control conditions, and it includes emissions from all sources at the plant. However, care should be taken not to apply this method over too short a time span. Solvent purchases, production, and waste removal occur in their own cycles, which may not coincide exactly.

In cases where control devices destroy potential emissions or a liquid material balance is inappropriate for other reasons, plant-wide emissions can be estimated by summing the emissions calculated for specific areas of the plant.

Estimating NMVOC emissions from a coating operation (application/flash-off area and drying oven) starts with the assumption that the uncontrolled emission level is equal to the quantity of solvent contained in the coating applied. In other words, all the NMVOC in the coating evaporates by the end of the drying process. This quantity should be adjusted downward to account for solvent retained in the finished products in cases where it is quantifiable and significant.

Two factors are necessary to calculate the quantity of solvent applied; the solvent content of the coating and the quantity of coating applied. Coating solvent content can be directly measured; alternative ways of estimating the NMVOC content include the use of either data on coating formulation that are usually available from the plant owner/operator or pre-mixed coating manufacturer or, if these cannot be obtained, approximations based on the information in Table 3. The amount of coating applied may be directly metered. If it is not, it must be determined from production data. These should be available from the plant owner/operator. Care should be taken in developing these two factors to assure that they are in compatible units.

Where an estimate of uncontrolled emissions is obtained, the controlled emissions level is computed by applying a control system efficiency factor:

$$(\text{uncontrolled NMVOC}) \times (1 - \text{control system efficiency}) = (\text{NMVOC emitted}).$$

Not all potential emissions are captured and delivered to the control device. The control system efficiency is the product of the efficiencies of the capture device and the control device. Emissions from such sources as process waste water or discarded waste coatings may not be controlled at all. Not, the above equation applies when the solvent is destroyed or disposed of, not when it is reused.

Note: there is a considerable possibility for double counting here, because of the use of cleaning and thinning solvents. In general, thinning solvents are not covered elsewhere and need to be included in the total for this sector. Cleaning solvents for metals (specifically those used in metal degreasing) should not be included sectors covering paint application.

6. RELEVANT ACTIVITY STATISTICS

For the simpler methodology, the total quantity of paint which is used for each activity is required; some emission factors are referred exclusively to the quantity of paint (ie without considering diluents and cleaning solvents).

The alternative methodology for activity 060101 requires the knowledge of the number of painted vehicles and the average painted area of the vehicles. The alternative methodology for wood products industry (included in activity 060102) requires the knowledge of the number of painted pieces and the average painted area of each piece. The detailed approach can be used where either solvent usage data are available, or, alternatively, the solvent content of the coating and the quantity of coating applied.

In addition, the mass or relative proportion of sales of mater based and the mass of organic solvent based paint is required.

The detailed approach can be used where either solvent usage data are available or alternatively, the solvent content of the coating and the quantity of coating applied, is known.

7. POINT SOURCE CRITERIA

Within the CORINAIR inventory, vehicle painting units with a production capacity higher than 100,000 vehicles/year (or equivalent) are considered point sources; painting lines equipped for using low NMVOC emission paints must also be taken into account (activity 060101).

In addition to this, it has to be mentioned that, according to the CORINAIR '90 methodology, every plant emitting more than 1,000 Mg/year is a point source.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

Emission Source	Emission Factor (Quality Code)
Paint application: manufacture of automobiles	500 kg/tonne of paint ©
Other industrial paint application	500 kg/tonne of paint ©
Vehicles refinishing	280 kg/tonne of paint ©
Vehicles refinishing	600 kg/tonne of paint ©
Paint application: construction and buildings	300 kg/tonne of paint ©
Paint application: domestic use	400 kg/tonne of paint ©
Paint application: water based paint	30 kg/tonne of paint ©

The NMVOC emission factors refer to the total quantity of paint which is used: coating, paint, diluents, cleaning solvents. (ie the activtiy statistic is paint +diluents and cleaning solvents). An emission factor for vehicles refinishing, based on the activity rate for paint only would be higher, that is 600 kg/t of paint.

The above figures refer to uncontrolled emissions: the different control options can be taken into account by modifying of the emission factors and/or the activity indicator.

If alternative types of paint are used, the emission factors must be corrected taking into account the mean solvent contents of the paint, as shown in Table 3 for instance, if water base paint is used, NMVOC emission is about 30 kg/t of paint.

The above should only be considered as default emission factors, to be used if no better information is available. It may be possible to get better information by consulting, for example, the national product register or trade associations, for the national charactersitic solvent content of the different types of coating used in a country.

An alternative methodology for activity 0601 is to combine the number of automobiles produced with an emission factor depending on the quality of coating, the type of application systems and control devices. The emission factor proposed by CORINAIR '85 was 10 kg/vehicle (within the range 5-15kg/vehicle). A range of 6-11kg/vehicle has been obtained from a detailed survey made in Italy during years 1991 to 1993, which refers to plants having a production bigger than 100,000 vehicles per year.

More realistic values can be calculated by multiplying the average painted surface area of the vehicle by an emission factor referred to the unit painted surface. Table 7 summarises the range of emissions observed from small (surface area 65m²) and large (surface area 117m²) car painting; these emission factors are for essentially uncontrolled processes.

Table 7: Uncontrolled emission factors for car painting

Type of car	Painted surface area m ²	Type of paint	Typical NMVOC emissions	
			kg/car	g/m ²
Small	65	Solid	12.3	189
Small	65	Metallic	14.1	217
Large	117	Solid	31.6	270
Large	117	Metallic	33.2	284

Source: UK Society of Motor Manufacturers & Traders

In order to estimate total emissions, it is therefore necessary to take into account the distribution of production by car size in each country. As the actual average surface for each vehicle category may differ from those given in Table 5, the relevant emission factor must be interpolated. Currently small cars have an average surface of about 65 m², medium size cars of about 75 m², and large cars of about 90 m²; the production of these types of cars in the different EC-Member States is shown in Table 8.

Table 8: Breakdown by size of car production in the EC-Member States

Country	Small cars	Medium cars	Large cars
Belgium	10	80	10
France	8.6	41.5	49.9
Germany	0.3	18.7	81
Italy	42.7	32.2	15.1
Netherlands	10	80	10
Spain	40	60	-
United Kingdom	10.6	62.3	27.12

Source: Ziercock, 1993

As concerns the average painted areas of trucks, vans and buses, the following figures are available (IVECO FIAT, 1991):

truck cabins	60-75	m ² /vehicle
truck boxes	80	“ “
truck axles	4-8	“ “
truck chassis	11-25	“ “
vans	120	“ “
bus bodies	220-280	“ “
bus chassis	18-25	“ “

Total NMVOC emissions from existing plants currently amount to:

- 0.12 kg/m² on average for vans, trucks and passenger cars with more than 6 seats (but going up to 0.16 kg/m² in some cases);
- 0.5 kg/m² for buses.

Possible emission limits (yet to be discussed) are:

- 0.07 kg/m² (new plants) and 0.09 kg/m² (existing plants) from large installations for vans, trucks and passenger cars with more than 6 seats;
- 0.09 kg/m² (new plants) and 0.12 kg/m² (existing plants) from small installation for vans, trucks and passenger cars with more than 6 seats produced;
- 0.055 kg/m² (new plants) and 0.065 kg/m² (existing plants) for truck cabins which are not coated in the same facility as the truck chassis;
- 0.25 kg/m² (new plants) and 0.35 kg/m² (existing plants) from large installations for buses;
- 0.35 kg/m² (new plants) and 0.45 kg/m² (existing plants) from small installations for buses.

Emissions from the wood products industry (included in activity 060102) can also be estimated using an alternative methodology, in which emission factors are referred to the painted surface of the products. Emission factors depend on products' quality and application methods; the following values, which represent the current situation of the wood industry in Italy, can be used elsewhere to give an order of magnitude (Federlegno, 1994):

Case A	100 g/m ²
Case B	400 g/m ²
Case C	400 g/m ²
Case D	200-585 g/m ²
Case E	360 g/m ²
Case F	284 g/m ²
Case G	600 g/m ²

- Case A: painting on line of flat elements with prevalent use of polyester-based coating products and polyurethane-based finishing products
- Case B: painting on line of flat elements with use of polyester-based products both for coating and finishing
- Case C: spray painting of kitchens
- Case D: spray painting of frames (the lowest value is referred to door frames and staff angles, the highest to furniture frames)

- Case E: spray painting of chairs
 Case F: spray painting of windows
 Case G: spray painting of assembled furniture

Note: it may be difficult to obtain specific activity statistics for these emission factors, nevertheless, they indicate the range of factors that are available.

9. SPECIES PROFILES

The solvents used in surface coatings are a mixture of aromatics, acetates, ethers and alcohols. An estimated breakdown of solvent usage in Western Europe is given in Table 9.

Table 9: Breakdown of solvent usage in paint application in Western Europe (OECD)

	Tonnes x 10 ³	% w/w
Aliphatic hydrocarbons	485	26.8
Aromatic hydrocarbons	560	30.9
Alcohols	255	14.1
Other oxygenates	510	28.2
Total	1810	100.0

Source: Edwards, 1986

National, speciated surveys can very well serve as the first step in inventorying of solvent losses. Some countries have made such surveys, and this kind of investigation should be encouraged to keep extrapolations at a minimum (see Tables 10 to 14). These data are generally assigned a data quality B.

Table 10: Reported solvent emissions from paint application per substance group (% ww)

Species	France (1985)	Germany (1986)	Italy (1987?)	Sweden (1988)	UK (recent)
Alkanes	29.6	11	13.4	15.6	11.4
Aromatics	18.4	23	42.1	26.4	49.4
Alcohols	28.8	17.8	11.5	24.0	13.8
Esters	8	17.8	11.5	23.6	6.3
Cellusolves		11.5	7.7	8.4	4.8
Ketones	14.6	10.4	11.5	2	12.5
Chlorinated	0.6	6.9	1.5	-	0.5
Other	-	1.6	0.8	-	1.2

Source: Veldt, 1993

Table 11: Speciated profile of the paint industry in the United Kingdom

Species		wt %
<u>Aliphatic hydrocarbons</u>	white spirit	8.0
	SBP solvent	3.4
<u>Aromatic hydrocarbons</u>	toluene	12.8
	xylene	16.9
	styrene	2.4
	160 - 180 boiling	12.4
	180 - 220 boiling	5.2
<u>Alcohols</u>	ethanol	1.3
	propane-2-ol	0.9
	2 methyl propanol	2.2
	butanol	3.1
	butanan-2-ol	1.9
	diacetone alcohol	1.9
<u>Esters</u>	ethyl acetate	1.9
	butyl acetate	2.3
<u>Ketones</u>	acetone	2.6
	butanone	2.9
	2 methyl panthan-4-one	4.0
	cyclohexanone	1.3
	Bisol K	1.3
<u>Glycols/ethers</u>	butyl glycol	1.0
	methoxy propanol	0.7
	Other	8.6

Source: Richardson et al., 1991

Table12: Speciated profile of emissions from the application of a waterbased paint (California, 1990)

Species	wt %
isomers of undecane	1.0
n-decane	0.21
n-undecane	0.12
n-butyl alcohol	20.09
2- (2-butoxyethoxy)-ethanol	0.78
1-ethoxy-2-propanol	1.46
2-ethyl hexanol	1.01
diacetone alcohol	0.78
ethylene glycol	0.58
hexylene glycol	1.43
dibutyl ether	0.24
2-butyltetrahydrofuran	0.15
vinyl acetate	0.12
methyl palmitate	0.36
methylal	26.97
substituted C9 ester (C12)	28.58
methyl amyl ketone	1.04
methyl chloride	0.55
dichloromethane	5.52
ethyl chloride	0.62
1-chlorobutane	2.21
3-(chloromethyl)-heptane	0.62
benzene	0.36
ethylisopropyl ether	5.20

Source: EPA, 1990

Table 13: Speciated profile of emissions from the application of a lacquer

Species	wt %
isomers of nonane	4.43
heptane	10.17
methylcyclohexane	15.25
2,4 - dimethylhexane	0.76
ethylcyclohexane	0.79
n-butyl acetate	14.90
isomers of xylene	1.04
toluene	44.59
o-xylene	3.14
ethylcyclopentane	1.68
trimethylcyclopentane	1.29
trimethylcyclohexane	0.81
methylheptane	1.14

Source: EPA, 1990

Table 14: Speciated profile of emissions from auto-body repair

Species	wt %
isomers of octane	1.27
isomers of decane	0.94
isomers of undecane	0.57
C9 olefins	0.94
C10 olefins	0.20
C11 olefins	0.03
isomers of C ₉ H ₁₆	0.02
heptane	4.35
nonane	2.48
methylcyclohexane	3.93
cyclohexane	0.32
ethylcyclohexane	1.57
C7 olefins	0.05
dimethylpentanol	0.41
butoxyethoxyethanol	0.57
hexadecanoic acid	0.01
butoxyethoxyethanol acetate	3.23
butoxybutene	1.75
ethylhexanoate	0.11
methylmethylpropenoate	0.32
dimethylpentanedioate	0.08
dimethylpentanedioate	0.81
tetramethylpentanone	1.30
nonenone	6.77
isomers of xylene	20.67
isomers of butylbenzene	9.10
isomers of propylbenzene	4.36
benzene	1.51
toluene	8.54

Source: EPA, 1990

10. CURRENT UNCERTAINTY ESTIMATES

A data quality C has been assigned to both emission factors and production statistics, and therefore to emission estimate (Passant, 1993). The range of emission factors for vehicles suggest at least a 50% uncertainty.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Estimating emissions from surface coating operations is very site-specific because of the wide range of coating formulations and the variety of coating techniques in use. The only realistic option that can be generally used to improve emission estimates is to apply the detailed methodology, based on solvent mass balances.

Another aspect is the variation of paint types. This requires good activity data, which may not be present, particularly with the increasing use of alternatives to high solvent paints.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Emissions from industry (activities 060101, 060102 and 060103) can be disaggregated using the relative number of industrial employees as a surrogate pattern for emission distribution. The necessary assumption of uniform NMVOC emission rates for all industry branches is a source of considerable uncertainty. Emission figures for industrial paint application performed in larger installations (ie all those referring to the mechanical industry) can be disaggregated through the use of other indicators. Emissions from the domestic use of paints (activity 060104) can be disaggregated according to the population distribution, assuming a constant value of per-capita paint consumption.

In principle, activity 060101, industries could be point sources. Activity 060103 could be distributed according to population, or housing, rather than industrial employment

13. TEMPORAL DISAGGREGATION CRITERIA

Temporal allocation of emissions from industrial and professional paint application (activities 060101, 060102 and 060103) can be derived from monthly production statistics and from information on operating schedule, workshifts, week-end interval etc. For instance, it can be assumed that professional architectural applications, and the relevant emissions, take place only in daylight (this does not apply to the Nordic countries).

Emissions from the domestic use of paints are equally distributed during the day; they can take place both on working days and on holidays. In the absence of specific surveys, a reasonable assumption is that emissions on Saturdays are twice as high as those on the other days of the week (Obermeier et al., 1991). In addition, there is a seasonal aspect. Most painting for 060103/4 can be expected in the spring and summer.

Solvent vaporization from paints and varnishes generally lasts for some hours from its application. The duration of this process obviously depends on a number of parameters describing drying conditions; a default assumption can be the following (Obermeier et al., 1991);

- for industrial uses, 80% of the solvent is released as soon as it is applied, and 20% in the following hour;
- for architectural uses, 50% of the solvent is released as soon as it is applied, 20% during the following hour, and 10% during each of the following three hours.

14. ADDITIONAL COMMENTS

Frequently, trade balance figures can provide a good overall figure than the use of surrogate statistics, although the level of detail is less.

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

Trade balance (import-export) and production statistics of a country may be compared to total emissions from solvent use. Per-capita emission factors can also be used to verify emission estimates: available figures show that per-capita emissions from the paint application sector are strikingly uniform (see, for instance, Table 17).

Table 17: Solvent emissions from paint application - per capita (kg/cap.year)

Country, region	Reference year	Per capita solvent emissions
Austria	1993	7.0
Canada	1985	4.8
Finland	1988	5.55
France	1985	4.8
Germany	1986	6.8
Italy	1987?	4.55
Japan	1983	6.4
Netherlands	1990	4.5
Norway	recent	4.5
Poland	1989	4.45
Sweden	1988	4.7
United Kingdom	recent	4.8

Source: Veldt, 1993

Available statistics do not generally break down consumptions by individual activities. Some figures are available for France and for the United Kingdom (Akkenabdm 1992; Passant 1993); they can be used to derive per-capita emission factors referring to the individual activities:

- construction and building: France 1.4 kg/cap.y, Netherlands 1.7 kg/cap.y, United Kingdom 0.5 kg/cap.y;
- domestic use: France 0.6 kg/cap.y, Netherlands 1.1 kg/cap.y, United Kingdom 0.5 kg/cap.y.

The alternative approaches proposed for estimating emissions can also be used to check estimates carried out by means of the baseline methodology.

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19. RELEASE VERSION, DATE AND SOURCE

Version 1.5

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Source: Domenico Gaudio, Silvia Brini,
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SNAP CODE :	060201
SOURCE ACTIVITY :	Metal Degreasing
NACE CODE :	28-35
PARCOM-ATMOS CODE :	2.9.2

1. ACTIVITIES INCLUDED

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, fiberglass, printed circuit boards and other surfaces.

2. CONTRIBUTION TO TOTAL EMISSION

Table 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Metal Degreasing	060201	-	-	1.8	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

3. GENERAL

3.1 Description of activities

The three basic types of solvent cleaning are

- Open top vapor cleaners (OTVC's)
- In-line (cold and vapor) cleaners (or conveyORIZED cleaners)
- Batch cold cleaners

The vast majority of halogenated solvent use is in vapor cleaning, both open top and on-line.

The five commonly used halogenated solvents are:

- methylene chloride (MC)
- tetrachloroethylene (PER)

- trichloroethylene (TRI)
- 1,1,1-trichloroethane (TCA)
- trichlorotrifluoroethane (CFC-113)

The primary solvents used in batch cold cleaners are mineral spirits, Stoddard solvents and alcohols.

3.2 Definitions

Solvent degreasing	removing fats, oils, wax or soil from surfaces with non aqueous solvents such as petroleum distillates, chlorinated hydrocarbons, ketones and alcohols.
MC	methylene chloride
TCA	1,1,1-trichloroethane
TRI	trichloroethylene
PER	tetrachloroethylene
CFC11	trichlorofluoromethaan
CFC113	1,2,2-trichlorotrifluoroethane
HS	halogenated solvents

4. SIMPLER METHODOLOGY

The simplest way of calculating emissions from degreasing is based on solvent use statistics and appropriate emission factors, in combination with assumptions about the distribution over the different environmental compartments.

5. DETAILED METHODOLOGY

A mass balance over an individual plant is the best approach.

6. RELEVANT ACTIVITY STATISTICS

Statistics from national or international statistical publications about solvent use should be used as a basis for the calculations.

7. POINT SOURCE CRITERIA

The emissions can be regarded as a diffuse area source.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

In table 2 solvent loss emission factors are given for degreasing operations [1].

Table 2: Solvent loss emission factors for degreasing operations.(Emission factor quality rating: C)

Degreasing technique	Activity	Uncontrolled emission factor ¹
All ²	Solvent used	1000 kg/Mg
Cold cleaner Entire unit ³ Waste solvent loss Solvent carry out Bath and spray evaporation Entire unit	Units in operation Surface area and duty cycle ⁴	0.30 Mg/yr/unit 0.165 Mg/yr/unit 0.075 Mg/yr/unit 0.06 Mg/yr/unit 0.4 kg/hr/m ²
Open top vapor Entire unit Entire unit	Units in operation Surface area and duty cycle ⁵	9.5 Mg/yr/unit 0.7 kg/hr/m ²
Conveyorized, vapor Entire unit	Units in operation	24 Mg/yr/unit
Conveyorized, nonboiling Entire unit	Units in operation	47 Mg/yr/unit

¹ 100% nonmethane VOC.

² solvent consumption data will provide much more accurate emission estimates than any of the other factors presented.

³ emissions generally would be higher for manufacturing units and lower for maintenance units.

⁴ for trichloroethane degreaser.

⁵ for trichloroethane degreaser. Does not include waste solvent losses.

In table 3 emission factors are given for the emissions of non-methane VOC emissions from small cold cleaning degreasing operations.

Table 3: VOC emissions from small cold cleaning degreasing operations (emission factor quality rating: C)

Operating period	Per capita emission factor
Annual	1.8 kg ¹
Diurnal	5.8 g ²

¹ include 25% 1,1,1-trichloroethane, methylene chloride and trichlorotrifluoroethane

² assumes a 6 day operating week (313 days/yr)

9. SPECIES PROFILES

Emissions from metal degreasing should be related to the solvent use. A profile of the solvents used, which may differ from country to country, should be used.

10. CURRENT UNCERTAINTY ESTIMATES**11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY**

The weakest aspect is the lack of sufficiently accurate statistics about solvent use.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Metal degreasing is a process that is used in a great number of small plants. Concentrations of these plants in a certain industrial area may be considered as point sources on a regional level if plant specific data are available.

13. TEMPORAL DISAGGREGATION CRITERIA

Metal degreasing is a process that is usually used during the daytime only.

14. ADDITIONAL COMMENTS**15. SUPPLEMENTARY DOCUMENTS**

PARCOM-ATMOS Emission factors Manual

16. VERIFICATION

Verification of the calculated emissions may be done by measurements at the plant level.

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BSM Gesellschaft für Betriebsberatung, Dusseldorf
TAUW Infraconsult B.V.

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SNAP CODE : 060202

SOURCE ACTIVITY TITLE : Dry Cleaning

1. ACTIVITIES INCLUDED

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

2. CONTRIBUTION TO TOTAL EMISSIONS

At present, annual NMVOC emissions from the dry cleaning industry in the European Union account for about 77,000 tons, i.e. 2.3% of total emissions from solvent evaporation, 0.6% of all stationary anthropogenic NMVOC emissions and 0.4% of all anthropogenic NMVOC emissions.

3. GENERAL

3.1 Description

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

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

Clothes are first cleaned in a solvent bath, followed by drying in hot air. The solvents are regenerated and the dirt and grease from the cleaning process are removed as a waste product. Emissions arise from evaporative losses of solvent, primarily from the final drying of the clothes, known as deodorisation. Emissions may also arise from the disposal of wastes from the process.

The most widespread solvents used in dry cleaning, accounting for about 90% of the total consumption, are chlorinated solvents like tetrachloroethane (also called tetrachloroethylene or perchloroethylene (PER)), trichloroethylene, 1,1,1-trichloroethane and methylene chloride.

To a lesser extent fluorinated solvents, mainly R113 (trichlorotrifluoroethane), and hydrocarbon solvents are used for dry cleaning. Hydrocarbon solvents are C₁₀ to C₁₃ aliphatic hydrocarbons with a vapour pressure of less than 0,1 kPa at 20°C. Recent international agreements which address substances responsible for stratospheric ozone depletion, are expected to lead to prohibition of certain solvents (e.g. chlorofluorocarbons and 1,1,1-trichloroethane) within a few years.

Two main types of machine are in use. In open-circuit, deodorisation of the clothes take place to atmosphere. Closed circuit machines have integral refrigerated condensers and no general venting.

Dry cleaning machines may be fitted with different types of abatement equipment:

- open-circuit machines for halogenated solvents with condensation by cold water;
- open-circuit machines for halogenated solvents with activated carbon filter;
- open-circuit dry cleaning machines for hydrocarbon solvents; in these processes quite often the drying is carried out in a separate machine;
- closed-circuit machines for halogenated solvents with integral refrigerated condensers and no general venting;
- new generation of closed-circuit machines for halogenated solvents; these machines are equipped with a refrigerated condenser and additionally with an activated carbon filter; which during the final step of the drying process (deodorisation) removes the last traces of solvent prior to unloading.

The following table shows the share of machine types for halogenated solvents in operation in some Member States (%).

Table 1: Share of Machine Types for Halogenated Solvents in Operation in Some EU Member States (%)

Country	Closed-circuit machines	Open-circuit machines	Open-circuit machines + activated carbon
Belgium	29	65	6
France	50	50	very few (large equipment)
Germany	45	0	55
Italy	50	50	
The Netherlands	30	5	65
Spain	44	53	3
United Kingdom	50	36	14

Source : Jourdan and Rentz, 1991

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

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

Further sources of emissions are the solvent-laden air discharge from storage tanks during filling and solvents retained on cleaned clothes and waste materials. Solvent emissions into the air represent about 90% of the solvent consumption for an open-circuit equipment and little more than 50% for a closed-circuit machine.

3.2 Definitions

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

3.3 Controls

- End of pipe abatement techniques:
 - condensation
 - carbon adsorption
- Process modifications:
 - use of totally enclosed machines
 - improvements in machine design
- Good housekeeping
- Regulations limiting concentrations in effluent

4. SIMPLER METHODOLOGY

The simpler methodology is to estimate emissions from solvent consumptions. It is assumed that all the solvent which is used is emitted: solvent lost in still residues and retained on cleaned clothes eventually finds its way to the atmosphere (Passant, 1993; UBA, 1989).

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

5. DETAILED METHODOLOGY

The detailed methodology requires a comparison of solvent consumption data with emission estimates based on technology and solvent dependent emission factors and activity statistics.

It is necessary to estimate the mass of clothes cleaned by each of five different machine types:

Open circuit machines - general

Open circuit machines - halogenated solvents

Open circuit machines - hydrocarbon solvents

Closed circuit machines - conventional, halogenated solvents

Closed circuit machines - new generation, halogenated solvents

6. RELEVANT ACTIVITY STATISTICS

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

7. POINT SOURCE CRITERIA

Not applicable

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

In the absence of better data, the following default emission factors may be used:

Emission Source	Emission Factor (Quality Code)
Simple Methodology	
All machines	100% of solvent use (D)
All machines	0.25 kg/inhabitant year (E)
Open-circuit machines ¹	0.8 kg/kg solvent consumption (D)
Closed-circuit machines ¹	0.4 kg/kg solvent consumption (D)
Detailed Methodology	
Open-circuit machines	125 g/kg material cleaned ©
Open-circuit machines for halogenated solvents	55 g/kg material cleaned ©
Open-circuit machines for hydrocarbon solvents	5 g/kg material cleaned ©
Conventional closed-circuit machines for halogenated solvents	30 g/kg material cleaned ©
"New generation" closed-circuit machines for halogenated solvents	10 g/kg material cleaned ©

1 - For emissions into the atmosphere directly from the machine

Open-circuit machines can be equipped with different abatement devices. No significant emission reduction has been observed for activated carbon filters without carbon recovery; solvent recovery enhances the abatement efficiencies to about 0.35 for systems without refrigeration and 0.45 for systems with refrigeration (Boldrino, 1989).

9. SPECIES PROFILES

Perchloroethylene (PER) is the most important solvent in the European dry-cleaning branch, amounting to approximately 90% within the Union, followed by the chlorofluorocarbon R113. All the other solvents are of minor importance. In the United States and Japan flammable petroleum solvents (white spirit) are also used, such as Stoddard or 140-F, which are inexpensive hydrocarbon mixtures similar to kerosene (U.S. EPA, 1985).

Table 2: Share of Different Solvents used for Dry-Cleaning in % (1991)

Country	PER	R 113	Others
Belgium	90	7	3
Denmark	90	10	0
France	93	5	2
Germany	90	10	0
Greece	?	?	?
Italy	85	14	1
Ireland	?	?	?
Luxemburg	97	0	3
The Netherlands	95	4	1
Portugal	97	0	3
Spain	95	5	0
United Kingdom	75	25	0
Austria	?	3	?
Finland	?	15	?
Japan	?	4	> 50
Norway	?	20	?
Sweden	?	50	?
Switzerland	?	25	?
United States	?	5	> 20

Source : Jourdan and Rentz, 1991

Small amounts of detergents are normally added to aid cleaning e.g. surface-active agents, solvents (alcohols, petroleum), optical whitener, resin finishing, disinfectant additives and aromatic substances. A profile for C₁₀ - C₁₃ hydrocarbon solvents in use in the United States is shown in Table 3. Data is in wt%

Table 3: Speciated Profile of Emissions from the Dry-Cleaning Using Petroleum Solvents

isomers of decane	11.28	methylheptane	4.19
isomers of undecane	7.92	methylnonane	0.91
isomers of dodecane	1.12	methyldecane	0.43
isomers of tridecane	0.05	methylundecane	0.17
C9 olefins	0.02	nonadiene	6.49
C10 olefins	2.15	pentylcyclohexane	0.24
C11 olefins	0.88	nonadiene	5.99
C12 olefins	0.12	dimethyloctanes	0.29
isomers of C10H18	0.07	dimethylundecane	2.48
isomers of C11H20	0.32	methylpropylcyclohexanes	0.21
C10H16	0.10	dimethyldecane	0.34
nonane	6.96	dimethylnonanes	0.10
methylcyclohexane	0.02	ethyloctane	4.27
ethylcyclohexane	0.59	ethylhexane	0.95
octanol	0.10	ethylmethylhexane	0.50
trimethylcyclohexanol	0.17	ethylmethylcyclohexanes	5.89
trimethylcyclopentanone	0.15	ethyltrimethylcyclohexane	0.35
tetramethylpentanone	0.64	ethylpropylcyclohexanes	0.02
isomers of butylbenzene	2.74	trimethylheptanes	0.55
trimethylbenzene	2.23	trimethylhexene	1.68
isomers of propylbenzene	0.98	trimethyloctanes	1.49
toluene	0.50	trimethyldecane	0.77
ethylbenzene	0.35	tetramethylcyclopentane	0.67
o-xylene	1.56	butylcyclohexane	0.55
cumene (isopropyl benzene)	0.34	methyloctanes	0.55
tert-butylbenzene	0.31	propenylcyclohexane	0.43
ethyltoluene	0.38	methyldecene	0.10
C5-alkylbenzenes	0.10	propylheptenes	0.17
C4-alkylphenols	0.38	diethylmethylcyclohexanes	0.05
C5-alkylphenols	0.17	isopropylmethylcyclohexane	0.10
dimethylbenzylalcohol	0.15	dimethyloctyne	2.11
chlorobenzene	0.26	pentylidenecyclohexane	0.47
octahydroindenes	0.17	octahydropentalene	2.01
tetramethylthioera	0.05	propylcyclohexane	0.45
benzothiazole	0.05	dimethylcyclohexane	0.55
naphtalene	0.35	trimethylcyclohexane	
methyldecalins	0.55	diethylcyclohexane	
decalins	0.60	dimethylheptanes	
m-xylene and p-xylene	2.26		

10. CURRENT UNCERTAINTY ESTIMATES

Uncertainty depends on the methodology. The highest uncertainty, >100%, would result from the use of per capita emission factors alone. Unverified solvent consumption data may also have a similar uncertainty.

The detailed methodology where comparisons between different estimation techniques are used, should give an accuracy of ± 10% or better.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

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

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

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

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

In the European Union, the dry cleaning sector is essentially made of small family units, using 1 to 2 machines of 10/12 kg capacity. In some countries, grouping of shops in "chains" may have a certain importance, but most of such groups operate only small units, so that pollution problems will be similar. For the whole Union, there are about 60000 dry cleaning shops. Table 2 shows the number of dry cleaning units in Member States, and the density of these units in relation to population.

Table 4: Main Characteristics of the Dry-Cleaning Sector in EU Countries

Country	Number of Dry-Cleaning Units	Density of Units in Relation to Population	Number of Machines
Belgium	1500	1/6500	
Denmark	1000	1/5000	
France	8000	1/7000	10000
Germany, F.R. of	10000	1/6000	12000/15000
Greece	3500	1/3000	
Ireland	800	1/4500	
Italy	20000	1/2500	
Luxemburg	50	1/8000	75/100
The Netherlands	660	1/20000	750
Portugal	1000	1/10000	1400
Spain	7500	1/5000	10500
United Kingdom	6500	1/8500	
Total	60510	1/5300	

Source : EEC, 1993

13. TEMPORAL DISAGGREGATION CRITERIA

Temporal allocation of emissions can be derived from monthly production statistics and from information on operating schedule, work-shifts, week-end interval etc.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

Verification is through the comparison of results using different methodologies:

Emissions estimates based on per capita emission factors.

Emissions based on solvent consumption data from the industry, trade associations etc.

Emissions based on emission factors per tonnage of material cleaned.

17. REFERENCES

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18. BIBLIOGRAPHY

19. RELEASE VERSION, DATE AND SOURCE

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SNAP CODE :

060303

060304

SOURCE ACTIVITY TITLE:

Polyurethane Foam Processing
Polystyrene Foam Processing

1. ACTIVITIES INCLUDED

This chapter deals with the application and subsequent discharge of organic compounds as blowing agents for creating plastic foams (Polyurethane and Polystyrene). These blowing agents need to be liquids which are characterized by a low boiling point. By application of external heat (polystyrene) or due to the reaction heat (polyurethane) the liquid evaporates and helps create the foam, without actually taking part in the reaction. Liquids used are CFC's (like F11, F12, F22), now being replaced by pentane and butane. Emissions are from the release of these blowing agents during foaming, or subsequently by the long-term release over several years, and are strictly evaporative. The production of the raw materials is included in SNAP code 040500 covering bulk chemical production.

Polyurethane (PUR) and polystyrene (EPS) are used in building construction, for heat insulation, and for packaging material. Characteristic is a high proportion of on-site foaming; i.e. only the production takes place in well defined production plants, the foaming (EPS) and the actual formation (PUR) directly at the site needed, which leads to direct emissions without foreseeable control.

2. CONTRIBUTIONS TO TOTAL EMISSIONS

	PUR	EPS	source
Baden-Württemberg (Germany)	0.1 %*	1.3 %	(Rentz et al, 1993)
Austria	0.5 %	0.2 %	(Orthofer et al, 1989)

*) long-term emissions not considered

3. GENERAL

3.1 Description

a) Polyurethane

Polyurethane is produced by the exothermic reaction of iso-cyanates with alcohols. About 80 % of the world production is foams (Stoekher et al, 1993), which are created by adding blowing agents. For soft polyurethane foams water may be used, which binds with iso-cyanate to form CO₂. Hard polyurethane foams utilize organic liquids as blowing agents (CFC's, now being replaced by alkanes), which evaporate due to the heat formation of the reaction. Hard foam is known for its good sealing and insulation properties. This also determines its use in refrigeration equipment as well as in the building and construction industry. While prefabricated compounds can be attributed to production sites directly, a

considerable proportion of polyurethane foam is produced and applied directly, for example at a construction site. Figures for Germany (Greenpeace, 1991) indicate that this "direct production" is almost as large as prefabrication (7000t CFC's used, vs. 9500t)

Another aspect of the sealing properties is, that the blowing agent is included into the cells of the structure, and only eventually released. According to German estimation (Rentz et al, 1990), only about 15 - 25 % of the blowing agent applied is released immediately, the rest is stored inside the cells of the foam and released eventually. Again, estimations are available for Germany (Plehn, 1990). The total amount of stored F11 (70000 t) is about 5 times the annual usage of CFC's for hard foam polyurethane.

b) *Polystyrene*

Polystyrene foams are primarily used for insulation material and for packaging material. EPS raw beads contain about 6 % pentane which is evaporated in the expansion stages and emitted during pre-expansion and moulding as well as during transport and storage (Achermann, 1992). Moulding is frequently performed in relatively small units (by heating EPS-beads with steam), and therefore relatively difficult to control. For Baden-Württemberg (Rentz et al, 1993), the emissions from EPS foam processing are about 10 times the emissions from polyurethane processing (without long-term emissions).

3.2 Definitions

Blowing agent: usually liquid substance which evaporates during the process (or releases gas) in order to expand the volume of the substrate ("blow") into a foam.

PUR: polyurethane

EPS: expandable polystyrene

3.3 Techniques

see 3.1

3.4 Emissions

Emissions are due to evaporation of blowing agents and consist of CFC's or alkanes (pentane, butane), respectively. All blowing agent used will be emitted eventually into the atmosphere, unless there exists some kind of capturing device. However, it may take years until all of the blowing agent is released from the cells of a PUR foam.

3.5 Controls

Replacement of CFC's by pentane and butane is reducing CFC emissions at the cost of increasing alkane emissions

Control / combustion of pentane, wherever defined production units are available

Reduction of long-term emissions by controlled destruction of used foam material (like the insulation of refrigerators)

Replacement of plastic foams as packaging materials.

4. SIMPLER METHODOLOGY

Emissions are derived from the production of PUR-foams and EPS foams times blowing agent content (see section 8). Assuming all of the blowing agent is eventually emitted, and constant annual production figures, the annual emissions are equal to the amount of blowing agent applied. In this case, the long-term emissions from foams produced in previous years are simply assumed to be equal to the amount of blowing agent retained in the foam produced in the current year.

5. DETAILED METHODOLOGY

Basically, emissions are determined the same way as for the simpler methodology. A number of parameters need to be taken into account, however:

Release of trapped blowing agents - According to figures presented by Rentz et al, 1993, about 30 % of the emissions due to hard PUR foam take place in the year of its formation, and 20 % in the years thereafter. In case of drastic changes of production, the production statistics of 4 years before the base year of the inventory need to be taken into account for the long-term releases.

Control measures (section 3.5) need to be taken into account for primary production. For EPS foaming, especially the abatement technology used in storage, pre-expansion and moulding has to be assessed (see section 8).

The blowing agent applied needs to be determined.

6. RELEVANT ACTIVITY STATISTICS

Industry statistics (production of PUR and EPS foams).

7. POINT SOURCE CRITERIA

No point sources are to be expected from this sector. Some large chemical plants may, however, include activities described here.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

Emissions are equal to the amount of blowing agent applied. Production figures are taken from the respective production statistics, the content of the blowing agent is listed in table 2.

Table 2: Content of blowing agent (%) in material before expansion

	Polyurethane (Rentz et al, 1993)	EPS (Achermann, 1992)
blowing agent content:	12 % (D) *	6 % ©

* figure derived for CFC's used as a blowing agent. No data are available for pentane as a replacement. Applying the same emission factor, the quality code has to be downgraded to (E).

8.1 Detailed methodology

For EPS foam processing, the application of controls needs to be considered. While no explicit emission factors can be given, a split of the emissions during different parts of the process may help attributing the efficiency of an abatement device (table 3).

Table 3: Relative emissions during different stages of EPS foam processing [6]

Transport/storage of raw beads	8 %
pre - expansion	27 %
Storage	17 %
Moulding	25 %
Final product*	23 %

* Diffuse emissions during use

9. SPECIES PROFILES

Depending on the blowing agent, emissions are F11, F12, F22, butane and pentane. The dominant agent will be pentane in the foreseeable future.

10. UNCERTAINTY ESTIMATES

As the production figures as well as the content of blowing agent can be found quite straightforwardly, the uncertainty is not too high and may be in the range of +/- 30% (see also Rentz et al, 1993), where uncertainty is estimated at +/- 20 %).

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

No information is available on the amount of blowing agent being transferred to other media (soil, water) than air.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Much of the emissions are associated with final distribution of goods (packaging) or building industry (insulation). These emissions are most appropriately attributed to population. Thus disaggregation of emissions should be performed according to population.

13. TEMPORAL DISAGGREGATION CRITERIA

Depending on the specific situation, about half of the emissions may be considered continuous, the other half process - orientated, concentrated on regular working times.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

The total emissions from the solvent sector (SNAP group 6) may be assessed applying a solvent balance (Import - Export + Production - Destruction) for a country. In many countries good statistics can be obtained which may be more reliable than the data available for individual source activities.

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19. RELEASE VERSION, DATE AND SOURCE

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SNAP CODE :**060310****SOURCE ACTIVITY TITLE :****Asphalt Blowing****1. ACTIVITIES INCLUDED**

Asphalt blowing is used for polymerizing and stabilizing asphalt to improve its weathering characteristics. Air blown asphalts are used in the production of asphalt roofing products, in the installation of built-up roofs and for the repair of leaky roofs. Air blowing of asphalt may be conducted at oil refineries, asphalt processing plants, and asphalt roofing plants. The emissions from a blowing still are primarily organic particulate with a fairly high concentration of gaseous hydrocarbon and polycyclic organic matter.

2. CONTRIBUTIONS TO TOTAL EMISSIONS

Asphalt blowing emitted the following percentages of anthropogenic emissions:

Table 1: Percent of Total Anthropogenic Emissions in 1990

Region	Particulate	SOx	NOx	CO	VOC
BG					0.1
Canada					0.04
DEw					1.0
ES					0.2
GR					<0.0
United States	0.2	0	0.004	0.001	0.004
CORINAIR					0.1

Emissions of SOx and NOx are most likely related to combustion for process heating (see SNAP Code 030100).

3. GENERAL**3.1 Description**

The process involves blowing air through a hot asphalt flux to raise the temperature at which it will soften. Blowing may be done in vertical or horizontal stills. Catalysts may be used to achieve certain properties and to increase the rate of reaction.

3.2 Definitions

Blowing still: A blowing still is a tank fitted near its base with a 'sparger', which increases contact between the air and the asphalt.

3.3 Techniques

Asphalt blowing involves the oxidation of hot asphalt flux which is achieved by the bubbling air of the blowing still. Air is forced through holes in the sparger into a tank of hot asphalt flux. The result is an exothermic oxidation reaction, which raises the softening temperature of the asphalt, as well as modifying other characteristics.

The process is highly temperature dependent, as the rate of oxidation increases rapidly with increases in temperature. Since the reaction is exothermic, the temperature rises as blowing proceeds. Temperatures must be kept safely below the flash point of the asphalt. The temperature is therefore kept at an optimum level of 260 °C during blowing by spraying water onto the asphalt surface. For some crudes auxiliary cooling may also be required.

Inorganic salts such as ferric chloride (FeCl_3) may be used as catalysts to achieve the desired properties and/or to increase the rate of reaction, thus decreasing the blowing time. Blowing times may vary in duration from 30 minutes to 12 hours, depending on the desired characteristics of the asphalt (softening point, penetration rate).

Stills may be either vertical or horizontal. Vertical stills are preferred because of the increased asphalt-air contact and consequent reduction in blowing times, as well as lower asphalt losses.

Asphalt blowing can be either a batch process or a continuous operation. Typically, stills at roofing plants and processing plants may be run as batch processes, while refineries may run in both modes, depending on the product demand.

In Canada, the percentage of asphalt produced that was sold for non-asphalt purposes, and was therefore likely to have been blown, ranged from 16.4 to 24.7 % of total reported asphalt sales in the period 1983 to 1991. In the U.S., 14% of total sales was reported for non-paving uses in 1991. (Asphalt Institute 1992)

3.4 Emissions

Asphalt blowing stills are sources of particulate hydrocarbon, gaseous hydrocarbon and carbon monoxide. Emissions of gaseous hydrocarbons are small because of the prior removal of volatile hydrocarbons in the distillation units.

The type of crude and characteristics of the asphalt may influence the emissions. For instance, the US EPA (1980) hypothesizes that uncontrolled emissions are higher for asphalts derived from the more volatile West Coast or Middle East crudes than from the mid-continent crudes. Process parameters influencing emissions include the blowing temperature, air rate, design/configuration of the still, and the type of product desired (e.g. saturant or coating asphalt).

3.5 Controls

Process controls include the following:

1. vertical rather than horizontal stills;
2. asphalts that inherently produce lower emissions;
3. higher flash point asphalts;
4. lower asphalt blowing temperatures.

Thermal afterburners in combination with closed capture systems are used to control combustible emissions from asphalt blowing stills. Although they consume less supplemental fuels, catalytic afterburners cannot be used because the catalyst is subject to rapid poisoning and plugging due to constituents of the fumes from the process.

4. SIMPLER METHODOLOGY

The simplest inventory methodology is to combine total national production statistics with average emission factors to estimate total emissions. Emission factors used should reflect the level of control for the region being inventoried.

5. DETAILED METHODOLOGY

The detailed methodology would involve procuring production statistics and control information for each plant. The latter information would be used to select the most appropriate emission factor. This would be for the case where asphalt blowing stills are considered to be point sources. If they are considered to be area sources, then the detailed methodology is not applicable.

6. RELEVANT ACTIVITY STATISTICS

The total weight of asphalt blown is required to estimate emissions from asphalt blowing stills. This information may be available on a national or regional basis from industry; for example, the Asphalt Institute publishes annual asphalt usage statistics for the United States and Canada.

7. POINT SOURCE CRITERIA

Release estimates only for asphalt blowing are difficult to obtain. For a large roofing manufacturing location, the U.S. EPA (1980) reports that about 120,000 Mg/yr. of asphalt would be blown. Emissions for this blowing facility in (Mg), calculated with emission factors from AP-42 (see Table 4) and assuming approximately half saturant and half coating blowing (U.S. EPA 1994) are summarized in Table 2.

Table 2: Calculated Annual Emissions for A Large Blowing Still (Mg)

Saturant Blowing		
Particulates	198	8.4
Total organic compounds	40	0.1
Coating Blowing		
Particulates	720	not available
Total organic compounds	102	5.1

Thus this asphalt blowing operation does not qualify as a point source of criteria pollutants in the CORINAIR 1990 classification, where emissions should be in excess of 1000 Mg in a year for SO₂ or NO_x and 1500 Mg per year of NMVOC.

Note that the location of the still may be the most important parameter in determining if it is a point source under the CORINAIR system: stills located at a refinery would likely be inventoried as a point source because the rest of the facility will qualify for this designation. Stills at other locations may qualify depending on total production and/or what other emission sources, such as combustion sources, are present.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

Passant (1993) used the emission factors for asphalt blowing listed in Table 3.

Table 3: Emission Factors for Asphalt Blowing (Passant 1993)

	NMVOC	Data	Data
Asphalt blowing	Emission Factor	Quality	Source
controlled	27.2 kg/t asphalt	D*	Robinson and Sullivan 1992
uncontrolled	0.54 kg/t asphalt	D	Robinson and Sullivan 1992

* An estimate based on an engineering calculation derived from a number of relevant facts and assumptions

Emission factors from the U.S. EPA compilation of air pollutant emission factors for asphalt roofing manufacturing plants are summarized in Table 4.

Table 4: Emission Factors for Asphalt Blowing (U.S. EPA 1994)

Operation	Particulates	TOC ^a
	Emission Factor (Data Quality) (kg/Mg asphalt processed)	
Uncontrolled		
Saturant	3.3	0.66 (E)
Coating	12	1.71 (E)
Controlled		
Saturant	0.14	0.0022 (D)
Coating		0.085

^a total organic compounds, ^b both processes are controlled with after burners

For blowing stills associated with petroleum refineries, the U.S. EPA (1985) cites an uncontrolled VOC emission factor of 30 kg/Mg of asphalt, stating that emissions may be

controlled to negligible levels by vapour scrubbing, incineration or both. No quality factor is given.

9. SPECIES PROFILES

Passant (1993) used the general speciation profile summarized in Table 5 for emissions from petroleum refineries to characterize emissions from asphalt blowing.

Table 5: Asphalt Blowing - NMVOC Speciation (Passant 1993)

Compound	% Weight
Ethane	6.0
Propane	18.8
Butanes	30.5
Pentanes	17.2
Hexanes	8.4
Heptanes	9.8
Octanes	7.4
Cycloparaffins	1.9
Benzene	0.1

UN ECE groups: 2% group I; 73% group II; 25% group III.

POCP factor:43

10. UNCERTAINTY ESTIMATES

It is not possible to estimate the accuracy of estimates based on the emission factors summarized in section 8. Based on the low data qualities and the large differences in emission factors, the level of uncertainty is high. The comments received from other panel members suggest that the uncertainty is greater than a factor of 2.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Quality factors assigned to emission factors for NMVOC and CO are low. It is recommended that improvements be made in the emission factors for these sources through new testing programs for uncontrolled and controlled blowing of asphalt.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

If asphalt blowing is inventoried as an area source, emissions may be disaggregated based on population.

13. TEMPORAL DISAGGREGATION CRITERIA

Asphalt blowing may be expected to occur year round. The U.S. EPA indicates that a typical blowing plant at a roofing manufacturing site may operate 16 hours a day, five days a week. Similar information for asphalt blowing at other facilities was not identified.

14. ADDITIONAL COMMENTS

There is considerable uncertainty on how much asphalt is actually blown. For instance, asphalts used for paving in France may be blown.

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

Emissions estimates at selected facilities could be verified against plant measurements.

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SNAP CODE :**060403****SOURCE ACTIVITY TITLE :****Printing Industry****1. ACTIVITIES INCLUDED**

Five main printing techniques have been identified:

- Offset
 - Cold set web offset
 - Heat set web offset
 - Sheet fed offset
- Rotogravure
- Flexography
- Letterpress
- Screen Printing

Only the printing processes listed above and the related coating and laminating processes are considered in this section.

Note: printing processes may involve the use of lacquers, adhesives and solvents for cleaning. There may therefore be overlapping with the SNAP categories 060108, 060201, 060405. It is important to ensure that 'double counting' does not occur.

The types of industries and the main techniques used may be classified as follows :

Press - Printing of daily newspapers.

- Cold set web offset is the main technique
- Letterpress is used in some rural areas.

Edition/Publication - Printing of books, magazines, catalogues, advertisements.

- Cold set web offset
- Heat set web offset
- Sheet fed offset
- Rotogravure
- Screen printing

Packaging - printing of products for packaging, e.g. cardboard, corrugated cardboard, paper, flexible plastic, aluminium foils and cellulose films.

- Sheet fed offset
- Rotogravure
- Flexography
- Screen printing

Rigid Metallic Packaging - printing of food cans, aerosol cans, caps and closures.

- Sheet fed offset. (Note that subsequent varnishing is also used which results in higher VOC emissions).

Decoration - manufacture of wall coverings, floor coverings etc on paper and plastic.

- Rotogravure
- Flexography
- Screen printing

2. CONTRIBUTION TO TOTAL EMISSIONS

Table 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Printing Industry	060403	-	-	1.3	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

In addition, most of this emission, perhaps 87%, is thought to come from the packaging and decoration sectors (Allemand 1990). Swedish data (1990) on emissions by technique is given below:

Technique	% contribution to total emissions from printing
Offset	29
Flexography and rotogravure	78
Screen Printing	3

3. GENERAL

3.1 Description

Printing involves the use of inks which may contain a proportion of organic solvents. These inks may then be subsequently diluted before use. Different inks have different proportions of organic solvents and require dilution to different extents. Printing can also require the use of cleaning solvents and organic dampeners. Ink solvents, diluents, cleaners and dampeners may all make a significant contribution to emissions from industrial printing involves the application of inks using presses. The largest plants may have as many as ten presses.

3.2 Definitions

Flexography means a printing process using an image carrier of rubber or elastic photopolymers on which the printing areas are above the non printing areas, using liquid inks, that dry through the evaporation of organic solvents.

Offset	means a printing process, using an image carrier in which the printing and non-printing area are of the same plane. The non-printing area is treated to attract water and thus reject ink. The printing area is treated to receive and transmit ink to the surface to be printed.
Rotogravure	means a printing process using a cylindrical image carrier in which the printing area is below the non printing area, using liquid inks, that dry through evaporation. The recesses are filled with ink and the surplus is cleaned off the non-printing area before the surface to be printed contacts the cylinder and lifts the ink from the recesses.
Screen	means a printing process in which the ink is passed onto the surface to be printed by forcing it through a porous image carrier, in which the printing area is open and the non-printing area is sealed off, using liquid inks, that dry through the evaporation of organic solvents.
Sheet-fed	means that the material to be printed is fed to the machine as separate sheets
Web-fed	means that the material to be printed is fed to the machine from a reel as distinct from separate sheets
Heat set	means a printing process where evaporation takes place in an oven where hot air is used to heat the printed material.

3.3 Techniques

The different printing process use characteristic inks with different proportions of organic solvents. Inks may be described as high solvent, low solvent or water based inks.

The solvent content of these types of inks have the following ranges when applied:

Ink type	Solvent content on application
High solvent	30 to 90%
Low solvent	5 to 30%
Water based	<5 to 20%

The solvent part of the ink may be evaporated at ambient temperatures or through heating in an oven. Certain specialist inks , containing very little solvent, may be cured using ultra violet or infra red radiation.

Solvents driven off through evaporation may be discharged untreated, recovered through carbon adsorption or destroyed via incineration.

Cleaning techniques range from wiping over equipment with a solvent cloth to the use of enclosed cleaning unit designed to recycle solvents.

3.4 Emissions/Controls

Emissions to air arise primarily from the organic solvents used in inks and for the dilution inks. This is especially true for rotogravure, flexography and screen printing. Solvents used in cleaning, the storage and handling of solvents and the use of organic solvents as dampeners

(commonly isopropanol especially in offset printing) are also important sources of emissions of organic compounds. The use of glues and adhesives, particularly in publication etc, is also a potential source of emissions.

Control options may be categorised as replace, reduce, recover or destroy.

Replacement

In some types of flexography and screen printing, water based inks may be used instead of organic solvent based inks. Water based solvents will contain organic compounds such as alcohols and amines. The proportion of organic compounds varies widely from less than 5% to as much as 20%.

The composition of ink can also be changed allowing ultra-violet, infra-red or electron radiation for curing the ink. Many of these curing methods use inks with almost no organic solvent content.

Less volatile cleaning agents may also be used.

Reduction

Possibilities for solvent reduction may be identified through solvent management plans. Changes in work practises, particularly during the storage, and handling of solvents and the cleaning of equipment, can lead to reduced fugitive losses. Technical changes including reduced etching depth in rotogravure can also reduce consumption.

Recovery

If a single solvent is used, e.g. toluene in rotogravure printing of newspapers and magazines, the solvent may be economically recovered for reuse, by means of activated carbon or other adsorption medium. Mixtures of solvents may also be recovered in this way, however, their immediate reuse is often not practical, and the recovered solvents are generally sent away for reprocessing or destruction.

Destruction

Destruction of solvent emissions may be achieved through oxidation to carbon dioxide and water. The various techniques may be categorised as follows:

Incineration

Thermal

Catalytic (also thermal but generally requires less additional fuel)

Biological

Biofilters

Bioscrubbers

In practice, thermal incineration is the most widely used method for destroying organic compounds emitted from printing processes. Destruction techniques are often better than 90% efficient, however, this may not necessarily mean a 90% reduction in emissions as solvents are also lost from storage, transportation, cleaning etc.

4. SIMPLER METHODOLOGY

The simpler methodology involves either the use of solvent consumption data or combining ink consumption with emission factors for the industry. Note, if solvent consumption data is used, then all solvents must be considered, including cleaning solvents, diluents and dampeners, as well as solvents present in the ink bought.

It should be possible to categorise the use of solvents/inks by each type of printing process. The following categories are recommended:

- Offset
- Rotogravure
- Flexography
- Letterpress
- Screen Printing

In the simpler methodology, unless solvent consumption data is used, no account is taken of the use of water based or low solvent inks, and no account is taken of the extent of controls such as incineration. The simpler methodology should therefore not underestimate the emission.

5. DETAILED METHODOLOGY

The detailed methodology requires an estimate to be made of the extent of control of emissions from printing processes and a reappraisal of the default emission factors used in the simpler methodology.

The extent of control and the reappraisal of emission factors is achieved through an audit of a representative range of printing processes. At least three types of printing processes should be included in the audit: rotogravure, flexography and offset. The audit should determine the total consumption of solvent at each plant, the control methods used, if any, and the estimated efficiency of the technique. Emissions data from the audit are compared with the default data used in the simpler methodology and a more accurate emission estimate is derived.

The greater the number of printing plants to be audited, the more accurate the final emission estimate. It is recommended that enough plants are audited to account for half of the total solvent consumption. Data from CITEPA (Allemand, 1990), suggests that for a country such as France, approximately 40 printing plants consume the majority of solvent used in the printing industry. These plants use rotogravure or flexography and are in the Edition/Publication, Packaging and Decoration sectors.

6. RELEVANT ACTIVITY STATISTICS

Relevant activity statistics include: solvent consumption per sector as listed in section 5; ink consumption per sector as listed in section 5.

7. POINT SOURCE CRITERIA

The distribution of solvent consumption amongst flexible packaging has been established for four European countries (Allemand 1990). The plants responsible for at least 50% of the emission typically consume 1kt or more of solvents each year.

This is therefore the recommended plants which consume 1000 tonne or more of solvent each year are identified for consideration as point sources, and that plants which emit 1000 tonne or more per year are reported as point sources criteria for consideration as point sources.

Note: consuming 1000 tonne or more of solvent does not necessarily mean emitting 1000 tonne or more of solvent if the solvent is destroyed by incineration for example.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

In the absence of better data, the following default emission factors may be used. The emission factors relate to the consumption of ink.

Sector	Technique	Emission Factor (kg/t ink consumed)	Qual.	Ref.
Press	cold set web offset	54	C	1
Edition/Publication	heat set web offset	182	C	1
	rotogravure	425	C	1
Packaging	sheet fed offset	437	C	1
	rotogravure	1296	C	1
	flexography	800	C	1
Rigid Metallic Packaging	sheet fed offset	437	C	1
	rotogravure	1296	C	1
	flexography	800	C	1
Decoration	rotogravure	1296	C	1
	flexography	800	C	1
	screen printing	935	C	1
Others	varnish	363*	C	1
	cleaning solvent	140	D	2

1 - Passant 1993

2 - Giddings 1991

* - per tonne of varnish

8.2 Detailed Methodology

Emission factors derived from an audit are compared with the default emission factors listed in 8.1. In particular, lower emission factors can be expected where low solvent or water based inks are used, or where recovery or destruction techniques are used to control emissions.

9. SPECIES PROFILES

The most common classes of solvents used in the printing industry as a whole are (SEPA 1990, Passant 1993):

- white spirit and paraffins
- aromatics
- alcohols
- esters
- ketones
- glycol ethers

Individual compounds identified include (USEPA 1988, SEPA 1990, Passant 1993)

- cyclohexane
- toluene
- xylene
- ethyl benzene
- diethyl benzene
- methanol
- ethanol
- isopropanol
- isobutanol
- cyclohexanol
- ethyl acetate
- acetone
- methyl ethyl ketone
- methyl isobutyl ketone

It has been found that the solvents used in different printing processes are a strong characteristic of the country or region. Unless better information is available, the following default species profile, with a quality code of D is suggested for the printing industry as a whole:

Alkanes (e.g. decane)	50%
Alcohols (e.g. isopropanol, ethanol)	35%
Aromatics (e.g. toluene)	15%
Ketones (e.g. methyl ethyl ketone)	10%

10. UNCERTAINTY ESTIMATES

Simpler methodology

An emission estimate based on emission factors, without taking into account control measures may have an uncertainty as high as 100%. An emission estimate based on solvent consumption, without taking into account control measures may have an uncertainty of 50%.

Detailed Methodology

An emission estimate based on an audit, taking into account control measures may have an uncertainty of 20%.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Simpler Methodology

The weakest aspects of the approach recommended above is the need to use quite detailed information activity statistics, namely the ink supplied to different types of printing processes in different market sectors. Such information may not be directly available and may have to be estimated.

In addition, the approach takes little account of the use of abatement systems, particularly destruction processes such as incineration. The impact of these systems would reduce the emission estimate.

Finally, information on cleaning and damping solvents is particularly poor.

Detailed Methodology

This requires audits of the major plants, perhaps 40 for a country like France. Such audits are time consuming, and may not be possible if solvent audits are not a requirement of process authorization.

Priority areas for improvement is a detailed review of the rotogravure and flexographic techniques to improve the current emission factors to at quality Code B and a methodology for assessing the extent of abatement and its effectiveness.

Note, in the EU the countries with the largest rotogravure and flexographic industries are thought to be Italy, Germany, UK and France (Allemand 1990).

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

In the simpler methodology, no point sources are defined. Spatial disaggregation should therefore be done on a population basis, or if possible, using the distribution of engineering workers.

In the detailed methodology, large printing processes are identified. The residual may be disaggregated according to population, or if possible, distribution of engineering workers.

13. TEMPORAL DISAGGREGATION CRITERIA

Large print works may work 24 hour shifts continually emitting VOCs. Smaller print works may only work single shifts of 8 hours during the day.

In the absence of other data, it may be assumed that emissions are relatively consistent over the course of a year.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

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16. VERIFICATION PROCEDURES

Verification of emission estimates will be primarily through inter-comparison between countries, since some countries can be expected to carry out the detailed methodology. Significant difference in emissions of organic compounds per tonne of ink used, or per capita may indicate poor quality data.

In addition, measurements carried out at individual printworks could be used to establish the actual efficiency of abatement equipment.

17. REFERENCES

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19. RELEASE VERSION, DATE AND SOURCE

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SNAP CODE :**060404****SOURCE ACTIVITY TITLE :****Fat, Edible and Non Edible Oil Extraction****1. ACTIVITIES INCLUDED**

Solvent extraction of edible oils from oilseeds. Drying of leftover seeds before resale as animal feed.

2. CONTRIBUTION TO TOTAL EMISSIONS

Emissions of NMVOC from the solvent extraction and subsequent drying of oilseeds represent between 0 and 0.5% of a country's total NMVOC emission.

For example, in the UK the contribution is 0.34% (Passant, 1993).

3. GENERAL**3.1 Description**

The extraction of oil from oil seeds is performed either mechanically or through the use of solvents, or both. Where solvent is used, it is generally recovered and cleaned for reuse. The seed may be subjected to solvent treatment many times before all the oil is extracted. The remaining seed residue is then dried and may be used as an animal feed.

3.2 Definitions**3.3 Techniques**

If the oil content of the seed is high, for example olives, the majority of the oil is pressed out mechanically. Where the oil content is lower, or the remaining oil is to be taken from material which has already been pressed, solvent extraction is used.

Hexane has become a preferred solvent for extraction. In extracting oil from seeds, the cleaned and prepared seeds are washed several times in warm solvent. The remaining seed residue is treated with steam to capture the solvent and oil which remains in it.

The oil is separated from the oil-enriched wash solvent and from the steamed out solvent. The solvent is recovered and re-used. The oil is further refined.

3.4 Emissions/Controls

Solvent recovery is an integral part of solvent extraction plant. The economics of a plant may be finely balanced on the proportion of solvent which is recovered. The efficiency of recovery is usually high, but is dictated by economic considerations, and will be limited to recovery

plant on which the capital investment can be paid for by reduction in expenditure on new solvent.

Emissions of NMVOC will also arise from the drying of spent oil seeds.

Emissions may be controlled by improving the efficiency of the solvent extraction plant and by adding abatement equipment such as water scrubbers to the drying plant.

4. SIMPLER METHODOLOGY

The simpler methodology is to combine an activity statistic with an appropriate emission factor for solvent extraction and for the drying of spent grain.

5. DETAILED METHODOLOGY

A more detailed methodology would combine activity statistics and emission factors for different vegetable oil types and for the production of different VOC species. It might also consider other stages within the oil extraction process.

6. RELEVANT ACTIVITY STATISTICS

For the simpler methodology, the relevant activity statistics are the quantities of oil extracted and seed used in units of tonnes per year. In addition, the total solvent consumption by the industry is a measure of the solvent required to replace that lost during the recovery process.

For the more detailed methodology, the activity for different oil types and for different NMVOC species are needed. Data on other stages within the oil extraction process could also be used.

7. POINT SOURCE CRITERIA

There are relatively few oil extraction plants in the UNECE area. These could be considered as point sources, if plant specific data are available. Otherwise the activity is a relatively small source of NMVOC and hence should be considered as an area source.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

Solvent extraction:

<u>Emission Factor</u>	<u>Quality Code</u>	<u>Reference.</u>
19 kg VOC. t ⁻¹ of seed	D	Finelt (1979)
6 kg VOC. t ⁻¹ of seed	D	Munday (1990)
0.85 kg VOC. t ⁻¹ of seed	C	Swannell et al. (1991)

Grain Drying:

<u>Emission Factor</u>	<u>Quality Code</u>	<u>Reference</u>
1.31 kg VOC. t ⁻¹ of seed	D	US EPA (1985)

8.2 Detailed Methodology

No data available.

9. SPECIES PROFILES

The only solvent identified is hexane (Rentz *et al.*, 1990), and any solvent which fails to be recycled will eventually be emitted. Hexane is therefore suggested as the major species emitted (Data Quality D). Aldehydes and Fatty acids are liberated during steam treatment (Swannell *et al.*, 1991).

10. UNCERTAINTY ESTIMATES

The range of emission factors available suggests that there is considerable variation from plant to plant on the efficiency of the solvent recovery systems, with older plant being considerably less efficient than new plant. If this is not taken into account then the emission estimate may vary by a factor of 20.

There is only one reference emission factor for the drying of seed. This may not be expected to vary as much as the efficiency of solvent recovery plants. Nevertheless an uncertainty estimate of 100% cannot be ruled out.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the methodology is the application of general emission factors to different types of plant and different types of feedstock. The methodology would be considerably improved if emission factors could be established for old and modern plants and for the different types of seed e.g. corn, cotton seed, sunflower, rape, soya-bean, peanut.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

(Plants should be considered as point sources if possible.)

13. TEMPORAL DISAGGREGATION CRITERIA

It may be assumed that emissions occur uniformly over diurnal and annual cycles.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

Passant N.R., Richardson S.J., Swannell R.P.J., Gibson N., Woodfield M.J., van der Lugt J.P., Wolsink J.H., and Hesselink P.G.M. Emissions of Volatile Organic Compounds (VOCs) from the Food and Drink Industries of the European Community. Atmos. Environ. 27A, 2555-2566, 1993.

16. VERIFICATION PROCEDURES

Emission estimates based on emission factors may be compared with data on the total solvent consumption of this industrial sector. Emission factors should also be verified through measurements if possible.

17. REFERENCES

Finelt S. Air pollution abatement facilities at soybean processing plants, J. Air Pollut. Control Ass. 29, 1192-1196, 1979.

Munday P.K. U.K. emissions of air pollutants 1970-1988. Warren Spring Laboratory, Stevenage, Herts, UK, 1990. Report Number LR 764 (AP).

Passant N.R., Emissions of Volatile Organic Compounds from Stationary Sources in the UK, Warren Spring Laboratory, Stevenage, UK, 1993, ISBN 0 85624 850 9.

Rentz O., Jourdan M., Roll C. and Schneider C. Emissions of Volatile Organic Compounds (VOCs) from Stationary Sources and Possibilities for their Control. Published by the Institute of Industrial Production, University of Karlsruhe, Germany, 1990. Report No. OBA 91-010.

Swannell R.P.J., Richardson S.J., Passant N.R., Woodfield M.J., van der Lugt J.P., Wolsink J.H., Hesselink P.G.M., Hecht V., Brebbermann D. and Bischoff H. Biodegradability and Emissions of Volatile Organic Carbon Compounds from the Food, Drink and Metal Degreasing Industries. Published by TNO Environmental and Energy Research, P.O. Box 6011, Delft, Netherlands for the Commission of the European Communities DG XII, 1991. Report No. R91/381.

United States Environmental Protection Agency. Compilation of air pollutant emission factors. Volume 1. Stationary point and area sources. 4th Edition, 1985. EPA Report AP-42. North Carolina, U.S.A.

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19. RELEASE VERSION, DATE AND SOURCE

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SNAP CODE :

060406

SOURCE ACTIVITY TITLE :

Preservation of Wood

1. ACTIVITIES INCLUDED

This chapter considers processes for the impregnation with, or immersion of timber in, organic solvent based preservatives, creosote and water based preservatives.

Wood preservatives may be supplied for both industrial and domestic use. Most of the information currently available on emissions relates to the industrial use of wood preservatives.

This section is not intended to cover the surface coating of timber with paints, varnishes or lacquer (see chapter B610).

2. CONTRIBUTION TO TOTAL EMISSIONS

Table 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Preservation of Wood	060406	-	-	0.6	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

The contribution to total NMVOC emissions from the preservation of wood varies greatly from country to country. It has been estimated (Giddings et al 1991) that the total for the EU is 47.5kt/a, varying between 0 and 1% of total NMVOC emissions from all sources in individual countries.

3. GENERAL

3.1 Description

Wood is preserved to protect it against fungal and insect attack and also against weathering. There are three main types of preservative: creosote, organic solvent based and water borne.

Creosote

Creosote is an oil prepared from coal tar distillation. Approximately 10% of the creosote used for wood preservation is made up of NMVOC. (Giddings et al, 1991). Creosote is the oldest form of wood preservative and is used for external applications such as telegraph poles and railway sleepers. Creosote is gradually being replaced by water borne preservatives.

Creosote may be mixed with petroleum fractions to produce carbolinium. This can be brushed onto the surface of the wood and is mainly for private use.

Water borne preservatives

Water borne preservatives consist of solutions of salts in water. Copper, chromium and arsenic types are the most widely used.

Organic solvent borne preservatives

These consist of approximately 10% active ingredient (Giddings et al 1991) and 90% organic solvent, usually white spirit or other petroleum based hydrocarbons.

Wood preservation is a major industry, with 6 million m³ of timber treated annually in the EU alone. Wood impregnation may be carried out at large plants, where control of emissions may be practical, or smaller plants, where add-on abatement systems could be prohibitively expensive.

3.2 Definitions

3.3 Techniques

The application of the preservative may be via vacuum processes, dipping, spraying or brushing. The vacuum process may vary slightly, depending on the preservative:

Creosote

Timber enters a chamber which may be pressurised with air. The chamber is flooded with hot creosote for 1-3 hours. After draining, a vacuum is applied to draw off excess creosote. The timber is then left to dry in the open air.

Water borne preservatives

These are applied in the same way as creosote.

Organic solvent borne preservatives

Timber enters a chamber which is subsequently evacuated. The chamber is flooded with preservative and pressurised for 5 to 20 minutes. After draining the chamber, a final vacuum is applied to draw off excess preservative. The timber is left to dry in the open air.

The application efficiency of the vacuum process, dipping and brushing is close to 90%. Spraying has a much lower efficiency of around 10% (Giddings et al 1991).

3.4 Emissions/Controls

NMVOCs result from the evaporation of organic solvents and the volatile components of creosote. These emissions may be fugitive (un-captured emissions) or captured and vented via a stack. Stack emissions may be controlled using waste gas cleaning (e.g. carbon adsorption, incineration etc).

Fugitive emissions occur throughout the handling, application and drying stages of the processes. Timber impregnation using the closed double vacuum process minimises the fugitive loss.

Emissions can be reduced by good solvent management, enclosing the process wherever possible so that air can be extracted through abatement equipment, and using alternative low solvent coatings where possible.

4. SIMPLER METHODOLOGY

The simpler methodology is to combine emission factors with activity statistics, taking into account the extent of control expected to be present.

5. DETAILED METHODOLOGY

The detailed methodology requires a solvent audit of each plant, quantifying the following:

- mass of solvent borne preservatives consumed per year:
- mass of creosote consumed per year
- mass of water borne preservatives consumed per year
- mass of NMVOC lost to land, or water
- mass of fugitive (un-captured) NMVOC emissions
- mass of captured NMVOC emissions treated for abatement
- efficiency of abatement equipment

6. RELEVANT ACTIVITY STATISTICS

The relevant activity statistics are:

- mass production/consumption of solvent borne wood preservatives
- mass production/consumption of creosote wood preservatives
- mass production/consumption of water borne wood preservatives

- mass/volume of wood treated with solvent borne preservatives
- mass/volume of wood treated with creosote
- mass/volume of wood treated with water borne preservatives

Given the difference between the use of wood preservatives by industry and for domestic applications, where possible activity statistics should be collected on both. For some countries, such activity statistics are not easy to obtain and it may be necessary to contact plants and trade organisations directly.

7. POINT SOURCE CRITERIA

It has been estimated (Giddings et al, 1991) that 1000 installations are involved in the treatment of timber in the EU, resulting in an emission of approximately 47kt. Thus the average emission per installation is 4.7t/a. This is relatively small for a point source and hence this activity can be considered as an area source.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The following emissions factors may be used. These are derivations from original data (Giddings et al, 1991).

Emission Factor	Quality Code	Reference
Uncontrolled		
100g/kg creosote	D	Giddings et al 1991
900g/kg sbp	C	Giddings et al 1991
0g/kg wbp	C	Giddings et al 1991
Controlled		
19g/kg creosote	D	See note below
180g/kg sbp	D	See note below

sbp - solvent borne preservative, wbp - water borne preservative. Controlled emissions assume that 90% of the solvent is captured, and the abatement efficiency is 90%.

If preservative consumption data is not available then the following assumptions may be made (Giddings et al 1991):

1m³ of wood requires 75kg of creosote

1m³ of wood requires 24kg of solvent borne preservative

1m³ of wood requires 6kg of water borne preservative (concentrated)

1m³ of wood is approximately 1t.

The above data relate to the industrial application of wood preservatives. Where the domestic use can be distinguished, then the emission factors will be higher. Data from the Netherlands (VOC Newsletter 8 and 9) suggest an NMVOC emission factor of 250g/kg of creosote.

8.2 Detailed Methodology

Emission factors should be derived through on-site measurements and a solvent audit. Otherwise, those factors listed above may be used.

9. SPECIES PROFILES

White spirit, petroleum distillates and creosote are the most common solvents used. They are complex mixtures of hydrocarbons, ranging in mass from isomers of hexane to isomers of dodecane, aromatics such as toluene and xylene, and some C6 to C12 alkenes.

10. UNCERTAINTY ESTIMATES

The greatest potential uncertainty lies in the extent of fugitive emissions and the efficiency of abatement equipment.

If fugitive losses vary between 5% and 20%, and abatement efficiency varies from 80% to 99%, then the range of emission factors for a controlled plant will be as follows:

6g - 40g/kg creosote

54g - 324g/kg sbp

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the methodology is the accuracy of the emission factors and the cost of on-site testing.

The recommended emission factors should be verified through on site measurement, particularly from the controlled (abated) use of creosote and solvent borne preservatives.

Those countries with the largest wood preserving industries could carry out a co-ordinated test programme. These include the UK and Germany.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Emissions from wood impregnation may be considered to be distributed according to population. However, given that industrial wood preservation is unlikely to be an urban business, a significant improvement in the spatial disaggregation would be made if the main territorial units where wood preserving takes place could be identified.

13. TEMPORAL DISAGGREGATION CRITERIA

Unless better information is available, emissions may be considered to occur evenly through out the diurnal and annual cycles.

14. ADDITIONAL COMMENTS

A number of national Trade Associations exist which may be contacted to obtain information on wood preserving in a given country. In addition, further information may be obtained from the West European Institute for Wood Preservation.

15. SUPPLEMENTARY DOCUMENTS

Zierock K-H., Methodology for the Estimation of Emissions from the Preservation of Wood [SNAP 060404], Envi Con, Weisbadener Strasse 13, D-12161 Berlin 41.

16. VERIFICATION PROCEDURES

For the simpler methodology, verification is through the solvent auditing of selected plants and comparison of this data with estimates based on emission factors. For the detailed methodology, inter-comparison of plants and a comparison with data from other countries is recommended.

17. REFERENCES

Giddings T.J., Marlowe I.T., Richardson S.J. Reduction of Volatile Organic Compound Emissions from Industrial Coating and Impregnation of Wooden Surfaces, 1991, CEC Contract No. B6611-90-005745.

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Richardson B.A., Wood Preservation., The Construction Press Ltd, 1978.

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SNAP CODE :

060408

SOURCE ACTIVITY TITLE :

Domestic Solvent Use

1. ACTIVITIES INCLUDED

This chapter addresses NMVOC emissions from the use of products which are sold for use mainly by members of the public as opposed to industry. It should be noted that many of these products, for instance cleaning agents, will be used by industry as well. The use of decorative paints, which is covered by a separate section (060104), is excluded from this section.

2. CONTRIBUTION TO TOTAL EMISSIONS

Table 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Domestic Solvent Use	060408	-	-	2.3	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

3. GENERAL

3.1 Description

VOCs are used in a large number of products sold primarily for use by the public. The activity can be subdivided into a number of sub-activities:

- Cosmetics & toiletries: products for the maintenance or improvement of personal appearance, health, or hygiene.
- Household products: products used to maintain or improve the appearance of household durables.
- Construction/DIY: products used to improve the appearance of the structure of buildings such as adhesives and paint remover. This sector would also normally include coatings, however these fall outside the scope of this section (see B) and will be omitted.
- Car care products: products used for improving the appearance of vehicles, to maintain vehicles or winter products such as antifreeze.

A further distinction can be made between aerosols and non aerosol products.

In addition to the above categories, pesticides such as garden herbicides & insecticides, and household insecticide sprays may be considered as consumer products. The bulk of agrochemicals however are produced for agricultural use, which would fall outside of the scope of this section. Emissions from agrochemicals may be estimated more accurately when treated in entirety. Hence, although some data on such products is included here, it is recommended that guidance on emission estimation is dealt with separately elsewhere.

3.2 Definitions

3.3 Techniques

NMVOCs are present in consumer products, primarily to act as solvents. In aerosols, NMVOCs such as butane and propane are also used as propellants, ie to discharge the product from the can when the valve is opened. Propellants generally act as solvents as well, thus switching from an aerosol to a non aerosol form of product will not necessarily reduce the proportion of solvent used in the product.

3.4 Controls

Emissions occur due to the evaporation of VOCs contained in the products during their use. Although for most products, all of the VOC contained in a product might be expected to be emitted to atmosphere, VOCs in products which are diluted in water will be lost mainly to waste water. Control of emissions from use of consumer products can only be achieved through reformulation of products to contain less VOC, or measures to promote the use of lower VOC products.

4. SIMPLER METHODOLOGY

The simpler methodology uses a single emission factor expressed on a per capita basis to derive an emission estimate for the activity by multiplying the emission factor by population.

5. DETAILED METHODOLOGY

The detailed methodology involves the collection of data on the VOC content of each type of consumer product, which can then be combined with consumption or production statistics in order to obtain estimates of quantities of VOC used in each category of product. The VOCs contained in some consumer products may not all be emitted to atmosphere, therefore, the VOC usage statistics are combined with suitable emission factors to derive emission estimates.

6. RELEVANT ACTIVITY STATISTICS

6.1 Simpler Methodology

The relevant activity statistics are national population figures.

6.2 Detailed Methodology

Production or preferably consumption statistics are required for each type of product, together with data on typical formulations so that the VOC content can be calculated.

7. POINT SOURCE CRITERIA

Domestic products should be considered as area sources.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler methodology

The following per capita emission factors have been derived from data for the UK, Canada, and the United States. Sources of these data are as follows:

UK	Atlantic Consulting, 1995
Canada	UN ECE, 1990
USA	EPA consumer products survey, 1995 (draft only)

Product category	NMVOC Emission Factor (g/year per capita)		
	UK	Canada	USA
Cosmetics & toiletries:			1061.3
Non aerosol	236.6	400.4	
Aerosol	536.3	384.8	
Household products:			431.4
Non aerosol	183.0	230.7	
Aerosol	55.4	346.9	
Car care products:			649.0
Non aerosol	324.3	649 ¹	
Aerosol	103.8	331 ¹	
DIY/buildings:			
Adhesives	70.1	47.6	277.2
Other ²	(221.9)	(221.9)	221.9
Aerosol propellant	785.5	included above	included above
Total	2492.3	2564.7	2640.7

1. These emission factors are given as 0.649g/annum/capita and 0.331g/annum/capita in the reference. The units are incorrect and should be kg/annum/capita. (personnel communication Deslauriers, Environment Canada 1995.

2. No data are available for Canada and the UK, so the USA figure has been used in order to enable a comparison of total emissions.

The overall emission factors for the three countries are similar, although there are some differences in the detail. The average of these three emission factors is recommended for calculating emissions from this sector.

Emission factor 2566 g VOC/person/annum

The US survey is extremely comprehensive and for many product categories includes formulation data for practically all products sold within that category. There is likely to be greater uncertainty over the proportion of solvent lost to atmosphere from such products, however, the overall quality of the US emission factors is likely to be good. A data quality B rating is probably realistic. The UK factors for non aerosol products are based on a smaller set of formulation data, however, the results have been discussed with industry who were in broad agreement with the estimates. A data quality B rating was given to these estimates. Emissions from aerosols are based on a survey by the UK aerosol manufacturers. These estimates are assigned a C data quality. The methods used to calculate the Canadian figures are not known and so no data quality rating can be given. The application of per capita emission factors to other countries does increase the uncertainties in emission estimates, however a data quality C rating seems justified for emission estimates calculated using the simpler methodology.

8.2 Detailed methodology

Studies such as that carried out in the US are useful in providing an extensive list of consumer products which contain VOC. However, the bulk of VOC emissions will be due to the use of a relatively small number of consumer products and these should be given priority in developing detailed estimates. Based on the US and UK data, the following products may contribute significantly to emissions:

Cosmetics and toiletries

Aerosols, all types
Styling aids, pumps
Styling gels
Other haircare, pumps
Antiperspirants/Deodorants, pump
Perfumes
After shave
Nail polish remover
Astringent
Healthcare products (external)
Rubbing alcohol

Waxes and polishes

Car care products

Aerosols, all types
Antifreeze
Brake fluids
Car waxes and polishes
De-icer, pumps
Engine degreasers
Windscreen washing fluid

Household products

Aerosols, all types
General purpose cleaners
Glass cleaner
Air freshener, slow release
Toilet blocks
Disinfectants

DIY/buildings

Carpet/tile adhesives
Pipe cements
Construction adhesives
Paint thinners
Paint remover
Solvents

The proportion of solvent contained in a product which is actually emitted to atmosphere will vary depending upon the manner in which it is used. The US and UK surveys assumed 100% VOC emitted to atmosphere except in the case of products which are either used diluted in water (ie dishwasher detergents, fabric detergents, bleach etc) in which case 1% was generally assumed, or products which are removed with water after performing their function (ie shampoos, soaps, toothpaste, household cleaners etc) which were assigned factors of between 5% and 50% VOC emitted to atmosphere. The data quality of estimates made using the detailed methodology will depend upon the quality and quantity of data used. In theory, it may be possible to obtain estimates deserving of an A rating.

9. SPECIES PROFILES

There are few data on the VOC species present in consumer products. A breakdown of VOC emissions from all consumer products has been given by a Swiss study (ATAL, 1992).

VOC compound class	Total emission (t/a)	% of total emission
Aliphatic hydrocarbons	3200	22
Alcohols	7300	50
Amines	210	1
Ketones	70	1
Esters	140	1
Ethers	2780	19
Aromatic hydrocarbons	450	3
Chlorinated hydrocarbons	190	1
Organic acids	190	1

The VOCs used are stated to include propane, butane, ethanol, isopropanol, ethyl acetate and butyl acetate. The following breakdown for emissions due to the use of aerosols is given in Passant, 1993.

Compound	% wt
Alkanes	60
Alcohols	35
1,1,1-trichloroethane	2
Esters & ketones	1
Dimethylether	2

The alkanes present in emissions will be predominantly butane and propane propellants. Ethanol is likely to be the most commonly used alcohol. The most widely used solvent in

cosmetics and toiletries is ethanol, and in the absence of more detailed information, it is recommended that all emissions from non aerosol cosmetics and toiletries are assumed to be ethanol. No data have been found for solvent types used in household and car care non aerosol products.

10. UNCERTAINTY ESTIMATES

The simple methodology relies upon a per capita emission factor. This was derived from emissions estimates for the US, UK and Canada. The estimates for the US and UK are likely to be quite accurate, perhaps +/- 20%. In the case of the US, since data on the VOC content was obtained for products representing most of the US market, the largest uncertainty will be the proportion of VOC in some products which is actually emitted to air. There are likely to be differences in the per capita consumption of products, as the formulations used from country to country vary due to economic, geographical and cultural reasons. The overall uncertainty of estimates derived from the simple methodology may therefore be high, perhaps as much as +/- 50%.

The use of the detailed methodology will remove one uncertainty which is present in the simpler methodology, namely, whether per capita consumption of products is the same in each country. Depending upon the quantity of data relating to formulations which can be obtained, there is no reason why the detailed methodology should not give an accuracy of perhaps +/- 20%. As with the US data, the largest uncertainty may be the proportion of VOC which is emitted to air.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the simple methodology is the use of per capita emission factors. There are likely to be differences in the use of consumer products in different countries due to, for instance, differences in car ownership, household size, wealth, lifestyle, product formulation, and climate. Emission estimates from other countries, derived using the detailed methodology should be fed back into the simple methodology to improve the emission factors. The adoption of a range of factors to reflect geographical and economic factors could be considered.

The detailed methodology should provide reasonably accurate estimates, depending upon the quantity of data on product VOC content which is available. More information is required on the VOC contents of consumer products, especially those products which contribute most to emissions. If the formulations used are comparable in different countries then default emission factors could be developed for use in the detailed methodology. The proportion of VOC in a product actually emitted to atmosphere may be considerably less than 100% for some products. Further research may be necessary to determine the fate of VOCs contained in such products.

Better speciated data are required, especially for household and car care non aerosol products.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

National emissions should be disaggregated by population.

13. TEMPORAL DISAGGREGATION CRITERIA

Assume continual emission throughout the year, unless better information is available, for instance monthly sales statistics. There is likely to be a strong diurnal variation in emissions with most occurring during the day.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

Verification of emission estimates can be carried out in a number of ways. The detailed methodology should be carried out in co-operation with product manufacturers who may be able to provide formulation data and production statistics. Estimates derived using the detailed methodology could be cross checked against estimates made for other countries. It should be borne in mind however that there may be significant differences in the use of VOCs in consumer products from country to country. Estimates may also be compared with estimates of the quantity of solvent sold to manufacturers of consumer products, derived perhaps in consultation with solvent suppliers. Formulation data, where obtained from manufacturers, could be verified through analysis of products.

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18. BIBLIOGRAPHY

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