SNAP CODES:	**060101** **060102** **060103** **060104** **060105** **060106** **060107** **060108** **060109**
SOURCE ACTIVITY TITLES:	**PAINT APPLICATION** ***Manufacture of automobiles*** ***Car repairing*** ***Construction and buildings (except item 060107)*** ***Domestic use (except item 060107)*** ***Coil coating*** ***Boat building*** ***Wood*** ***Other industrial paint application*** ***Other non industrial paint application***
NOSE CODE:	**107.01.01** **107.07.02** **107.07.03** **107.07.04** **107.07.05** **107.07.06** **107.07.07** **107.07.08** **107.07.09**
NFR CODE:	**3 A**

1 ACTIVITIES INCLUDED

This chapter deals with the use of paints within the industrial and domestic sectors as described by the source activity titles. Traditionally the term paint has often been used to describe pigmented coating materials only, thus excluding clear coatings such as lacquers and varnishes. However here the term paint is taken to include all materials applied as a continuous layer to a surface with the exception of glues and adhesives which are covered under SNAP 060405 (Application of glues and adhesives). Inks, which are coatings applied in a non continuous manner to a surface in order to form an image, are excluded by the definition given above.

Application of coatings during the manufacture of a number of other industrial products are covered by other SNAP codes:

060306	Pharmaceutical products manufacturing
060311	Adhesive, magnetic tapes, films and photographs manufacturing
060312	Textile finishing
060313	Leather tanning

The SNAP codes dealt with by this chapter are described below:

Activity 060101 "Paint application: manufacture of automobiles" refers to the coating of automobiles as part of their manufacture; it includes corrosion protection at point of manufacture; however it does not include the use of vehicle refinishing coatings (SNAP code 060102) or the application of aftermarket sealants, covered in the chapyer on underseal treatment of vehicles (SNAP code 060407). The application of sealants as part of the manufacturing process is covered here. Note that in some countries, only those paints manufactured for coating of high volume production vehicles (i.e. cars and light vans) are classified as automobile manufacture paints.

Activity 060102 "Paint application: car repairing" refers to the coating of road vehicles carried out as part of vehicle repair, conservation or decoration outside of manufacturing sites, or any use of refinishing type coatings where this is carried out as part of an original manufacturing process. In some countries, specialist paints which are used for coating small volume vehicles such as heavy goods vehicles and buses are classified as vehicle refinishing paints.

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 060105 "Paint application: coil coating" refers to the coating of coiled steel, aluminium or copper alloy strips as a continuous process.

Activity 060106 "Paint application: boat building" refers to all paints for the hulls, interiors and superstructures of both new and old ships and boats. Strictly speaking this sector should include paints for both marine and river craft although there may be differences between the classification of coatings in different countries.

Activity 060107 "Paint application: wood" refers to all paints for wood and wooden products but excluding the use of wood preservatives and creosote (see chapter for SNAP 060406)
Activity 060108 "Other industrial paint application" refers to all industrially applied paints for metal, plastic, paper, and glass substrates which are not covered by any of the other SNAP codes described here.

Activity 060109 "Other non industrial paint application" refers to the use of high performance protective and/or non corrosive paints applied to structural steel, concrete and other substrates and any other non industrial coatings which are not covered by any of the other SNAP codes described here. The sector includes coatings for offshore drilling rigs, production platforms and similar structures as well as road marking paints and non decorative floor paints.

2 CONTRIBUTION TO TOTAL EMISSIONS

Table 2.1: Contribution to total emissions of the CORINAIR90 inventory (*up to 25 countries*)

Source-activity	SNAP-code	Contribution to total emissions [%] including emissions from nature)							
		SO_2	NO_x	NMVOC[1]	CH_4	CO	CO_2	N_2O	NH_3
Manufacture of Automobiles	060101	-	-	0.8	-	0	-	-	-
Construction and Buildings	060103	-	-	2.4	-	-	-	-	-
Domestic Use	060104	-	-	1.4	-	-	-	-	-
Other Industrial Paint Application*	060102 060105 060106 060107 060108 060109	-	-	4.5	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
- = no emissions are reported
1 = contributions estimated (some countries reported total emissions to SNAP level 060100)
* = 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 2.2: Contribution of paint application to NMVOC emissions in different OECD regions

Country, region	Contributions to total 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

The use of paints is generally not considered relevant for emissions of heavy metals and persistent organic pollutants. Chlorinated solvents such as trichloroethylene and 1,1,1-trichloroethane are used in certain paint types in some countries although not in large quantities. Pigments which are compounds of metals such as lead, cadmium, chromium and zinc may be used in paints and could presumably be emitted to air, particularly where spraying is used as an application method. The European Atmospheric Emission Inventory of Heavy Metals and Persistent Organic Pollutants for 1990 includes emissions of copper from paint use in Spain (8% of total).

3 GENERAL

3.1 Description

This chapter covers the use of paints by industry, and by the commercial and domestic sectors. Most paints contain organic solvent which must be removed by evaporation after the paint has been applied to a surface in order for the paint to dry or ‘cure’. Unless captured and either recovered or destroyed, these solvents can be considered to be emitted to atmosphere. Some organic solvent may be added to coatings before application and will also be emitted. Further solvent is used for cleaning coating equipment and is also emitted.

The proportion of organic solvent in paints can vary considerably. Traditional solventborne paints contain approximately 50% organic solvents and 50% solids. In addition, more solvent may be added to dilute the paint further before application. High solids and waterborne paints both contain less organic solvent - typically less than 30% while powder coatings and solvent free liquid coatings contain no solvent at all.

Paints are applied using a variety of methods:

- spreading e.g. by brush, roller or paint pad;
- spraying, including air assisted and airless spraying, electrostatic spraying;
- flow coating, e.g. dipping, curtain coating, and roller coating;
- electrodeposition.

After application of the paint the surface is air or heat dried ***(stoved)*** to remove the volatile solvents from the coated surface.

3.2 Definitions

<u>Paint</u>: Traditionally a material containing pigment which is applied to a surface in order to form a film with protective, decorative and/or particular technical properties. Stains, which contain transparent pigments, are strictly speaking paints. In this chapter, the term paint should be understood to include unpigmented (clear) coatings such as lacquers and varnishes as well.

Varnish: Correctly speaking an unpigmented material which forms a hard glossy clear film and which cures by means of a chemical reaction as well as evaporation of the solvent. In practice the term is often used interchangeable with lacquer.

Lacquer: Correctly speaking an unpigmented material which forms a hard glossy clear film and which dries by evaporation of solvent alone i.e. where no chemical reactions occur. In practice the term is often used interchangeable with varnish.

Electrocoating: a process in which resins are electrolytically deposited on a substrate. The substrate is immersed in a water-borne resin system. A current is applied, with the substrate acting as either anode or cathode depending upon the resin system used. Resin in the vicinity of the substrate is destabilised and deposited.

3.3 Techniques

Depending on the product requirements and the material being coated, a surface may have one or more layers of coating applied. For example, a first coat may be applied to cover surface imperfections or to assure adhesion of the subsequent coatings, intermediate coats might provide the required colour texture and a final coat provide protection, durability and gloss. Coatings can be applied by a variety of methods such as brushing, rolling, spraying, dipping and flow coating; following application the surface is air and/or heat dried to remove the volatile solvents from the coated surface.

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 and generally four major steps can be recognised:

- metal pre-treatments;
- application and curing of primer coatings;
- application and curing of primer surfacer coatings;
- application and curing of topcoats.

Various auxillary operations such as sealant application and repair operations may also be carried out.

Pretreatments include the removal of rust using mineral acids and oils and other surface contamination using alkalis, followed by phosphating. The purpose of this is to modify the surface of the metal car body in order to improve the subsequent adhesion of the primer coating and also to increase the corrosion resistance of the metal. No NMVOC emissions have been reported for these processes. Primers can be applied by dipping, spraying or electrodeposition. Virtually all primers are now applied by the latter method. Primer surfacers and topcoats are applied by spraying which may be manual or automatic. It is increasingly common for metallic finishes to be applied using a basecoat plus clearcoat rather than a single topcoat with both colour and gloss properties. 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). All automotive coatings require stoving, at temperatures up to a maximum of about 200°C.

The application and curing of the primer, primer surfacer 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% to 50%.

Activity 060102 Paint application: Car repairing

Paints used for car repairs are often termed automotive or vehicle refinish paints. These products are commonly used to repair damaged bodywork although occasionally they can be used for purely cosmetic reasons. Typically a small area only will be repainted and spraying is always used to apply the coating. Because refinish paints are applied to a fully finished vehicle, fitted with fabric, plastic and rubber components, curing temperatures must be relatively low, a constraint which does not apply to original automotive coatings. Because of this, different technologies are used for the two types of paint.

It should be noted that refinish paints may be used by vehicle manufacturers to repair imperfections in original coatings. The use of such paints should be included under SNAP code 060102.

Activity 060103 Paint application: construction and buildings

Activity 060104 Paint application: domestic use

These two SNAP codes both refer to the use of paints for the interiors and exteriors of buildings. These paints are often referred to as decorative or architectural coatings and their use is covered by two SNAP codes, 060103 (construction and buildings) and 060104 (domestic use). The former refers to paint supplied to professional decorators and used by painting contractors, local authorities, government departments, industrial and commercial companies etc. and is often called trade decorative paint. The latter refers to paint sold to the general public as 'do-it-yourself' paint and is also known as retail decorative paint. There are only small differences in the formulations of these two types of paint and application methods are similar in both cases, although spray application may be used to a greater extent by professional decorators. Application by brush or roller are the preferred options.

It is possible to distinguish the main following applications of paints for the whole architectural sector:

- interior walls, ceilings and floors;
- exterior walls and floors;
- interior wood substrates: e.g. floors, furniture, doors, window frames;
- exterior wood substrates: e.g. fences, garden sheds, gable boards, garden furniture, wooden chalets;
- interior metallic substrates: e.g. radiators, tanks;
- exterior metallic substrates: e.g. fences, portals, garden furniture;

In addition, paints will fulfil a range of functions (e.g. undercoat or topcoat) and provide different finishes ranging from matt to gloss. The composition of the paint is very dependent upon the substrate being painted, the function and the finish required.

Activity 060105 Paint application: coil coating

Coil coating is the application of paints to continuous metal strip (generally steel, although aluminium and copper alloys are also painted) and is generally carried out on a large scale. The painted metals are used in the manufacture of kitchenware such as non-stick pans, white goods such as refrigerators and for building cladding. Roller coating is used to apply the paint which is then cured at high temperatures.

Activity 060106 Paint application: boat building

Paints for marine applications have some severe challenges to meet, in particular the need for excellent corrosion protection and anti-fouling properties. The formulation will depend upon the area being coated (e.g. hull or superstructure) and whether the paint is an original coating or a refinish paint. Marine paints are invariably applied as systems since all of the properties required cannot be met by a single paint. Paints are commonly applied by spraying although brushing is also used.

Activity 060107 Paint application: wood

Wood may be colour coated, stained or varnished. Application of paint is by roller or curtain coating (applicable only to flat stock) or spraying. Paints can be stoved or air dried with air drying frequently being carried out as an uncontained process. Fugitive emissions are therefore significant from many wood painting processes.

Activity 060108 Other industrial paint application

Paints supplied by industrial activities other than those already described are sometimes referred to as the general industrial sector. Products painted include agricultural, construction, and earthmoving equipment (‘ACE’), aircraft, cans and drums, caravans, domestic appliances, electrical components, freight containers, machine tools, military vehicles, motor vehicle components including engines, office equipment, paper and plastics, and toys. The scale of operation varies considerably, from large operations employing automated roller coating to smallscale manual spraying of paint. Processes may be enclosed or open air and both air dried and stoved coatings are used.

Activity 060109 Other non industrial paint application

This sector consists of the application of high performance protective and/or non corrosive paints to buildings, roads and other large structures. Most paint is applied in-situ by brushing, rolling or spraying, although some shop application of structural steel may occur.

3.4 Emissions

The most important pollutant released from painting activities is NMVOC. Particulate matter can also be emitted where spraying is used as an application technique, however many spraying operations are carried out in spray booths fitted with some type of particulate arrestment device. As mentioned earlier, heavy metal compounds, used as pigments, could be emitted to air, however, no emission factors are available.

NMVOC emissions result from the use of organic solvents in paints. The evaporation of the solvent is essential for the proper curing of the paint, however, it is possible to reduce the quantity of solvent needed either by substituting water or by applying the paint at a low(er) solvent content. Powder paints and solvent free liquid paints do not contain solvent and so NMVOC emissions are avoided. In the case of powder paints there is the potential for emissions of particulate matter.

A number of factors affect the mass of NMVOC emitted per unit of coated product. These include:

NMVOC (solvent) content of coatings:	emissions can therefore be reduced by decreasing the organic solvent content of a paint.
Volume solids content of coating:	since generally a given thickness or depth of solids needs to be applied to a surface, increasing the volume solids content of a paint means that a smaller volume of paint is required per unit of coated surface.
Paint usage:	Paint usage will be dependent upon the film thickness and the area painted. The extent to which these can be modified is fairly limited since they will be dictated by the design and function of the coated article. Decreases in paint usage might be possible in some cases through process improvements or improved process control.
Transfer efficiency	this is the percentage of solids in paint applied which remains on the surface of a coated article, and is thus an indication of the amount of paint wastage. Increasing the transfer efficiency means less paint wastage and therefore less needless NMVOC emission.

It should be noted that the first two factors are sometimes but not always connected i.e. it is possible to decrease the NMVOC content of a paint without increasing the solids content by substituting water for organic solvent.

Industrial painting processes can be fully enclosed and automated. Examples include coil coating, application of automotive electrocoat primers and coating of some metal and wooden substrates. These processes are, to a large extent, enclosed and emissions can be easily captured and treated by end-of-pipe technology. Many other painting processes are carried out manually, but are still to a greater or lesser extent enclosed, usually by special ‘booths’.

Again, the emissions can be captured and treated by end-of-pipe technology, although the economics of doing so are generally less favourable than in the previous case. Examples of these processes include vehicle repairing, the application of some automotive paints and the painting of many metal and wooden objects. Finally, some industrial painting processes are uncontained, for example the in-situ painting of ships and immovable structures.

Solvent is emitted from the moment the paint is applied. Some paints require stoving (heating in an oven) in order to cure fully, others are air dried. Emissions of solvent from ovens can be vented to control devices whereas air drying is often allowed to proceed in uncontained areas.

All painting activities lead to at least some fugitive emissions. The extent varies; for coil coating a figure of 5% has been reported (ERM), while emissions from the in-situ painting of ships are effectively 100% fugitive.

3.5 Controls

The best - and in some cases the only - way to control NMVOC emissions from paint application is to alter the process in such a way that no products containing solvent have to be used, or by reformulating the product in order to minimise the solvent content (see Table 3.1). 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 3.1 gives a brief review of alternative paints with typical solvent content.

Table 3.1: 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 liquid 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;
- absorption by a liquid;
- membrane separation;
- condensation;
- incineration;
- biological treatment.

Typical ranges of efficiencies for different control options are given in Table 3.2. More precise values can be given for each type of coating operation.

Table 3.2: 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	upto 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 proportion 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 atomised 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 atomisers can be used to atomise the paint. Typical transfer efficiencies are in the range from 60 to 95%. High volume, low pressure (HVLP) air atomised spray guns have recently been introduced and are designed to reduce paint wastage caused by overspray. They have been reported to be cost effective compared with conventional air atomised spray guns with paint usage reduced by 20% (Aspinwalls/NERA).

Activity 060101 Paint application: manufacture of automobiles

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

i) installation of abatement equipment;
ii) modification of the spraying process, the oven and air supply systems
iii) reformulation 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 (e.g. 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 3.3. 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 3.3: 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 are related to vehicle surface are, for instance, in the French legislation, an emission standard of 0.14 kg/m^2 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/m^2 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/m^2 have been drawn from national information and from the proposal for an EC Directive on solvent emissions.

Table 3.4: Emission rates in use or proposed in different legislation

Country	(kg/m^2 of car body)	Date of entry into force	Notes
Germany	0.060 0.120 0.035 0.045	3/1/86 (new), 3/1/91 (exist.) 3/1/86 (new), 2/1/91 (exist) May 91 ? May 91 ?	Uniform paint + lacquer[1] Metallized paint + lacquer[1] New plants Existing plants
Italy	0.060 0.120 0.090	note 2 note 2 July 93	Existing plants Single application solid coat (existing plants) Double application or metallic coat new plants (existing plants[3])
Sweden	0.126 0.030	92 97/8[4]	Actual average emission rate
UK	0.120 0.060 0.060	October 1996 October 1996 April 2001	Clear over base systems All other systems All systems
EU	0.045 0.060 0.090 0.090	00? 07? 00? 07?	>5000 monocoque cars per 12 months new plant >5000 monocoque cars per 12 months existing plant <5000 monocoque cars per 12 months new plant <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 060102 Paint application: car repairing

Although it is technically feasible to fit end-of-pipe abatement to vehicle refinishing processes, the use of reformulated products, coupled with improved transfer efficiency is a far more attractive option for process operators. Waterborne and high solids coatings are being developed and the use of high volume low pressure spray guns is increasing.

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.

The use of waterborne decorative coatings has increased with time, although the market share varies from country to country. Further progress can be expected, most technological difficulties have been or can be expected to be overcome with time, although currently waterborne paints can be more expensive than traditional alternatives. Some consumer resistance can also be expected.

Activity 060105 Paint application: coil coating

Incineration is currently used by some coil coaters and is likely to remain the most popular choice of abatement system. Due to the enclosed nature of these processes and therefore the high capture and destruction efficiency of incineration, only powder coatings are likely to reduce emissions from the sector further.

Activity 060106 Paint application: boat building

Since marine coatings are generally applied in-situ using spraying techniques, the most obvious options for reducing emissions are improved transfer efficiency (e.g. the use of HVLP spray guns) and reformulation of coatings. Some form of containment or capture of emissions might also be technically feasible in some cases.

Activity 060107 Paint application: wood

This sector covers a wide range of applications and so a variety of abatement options could be adopted. Reformulation of many paint systems may be possible with waterborne, high solid, powder and radiation cured paints all being developed. Where spraying is employed, solvent emissions can be reduced by switching to HVLP spray guns.

Many wood painting operations have significant fugitive emissions. These can be reduced by good solvent management, by the use of low solvent coatings, highly efficient application techniques and 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 (e.g. UV-cured paints) is the most promising option; powder or waterborne paints are less common, as they require high polymerisation 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).

Activity 060108 Other industrial paint application

As with painting of wood, this sector covers a wide range of applications and a variety of control techniques are also available to reduce NMVOC emissions. 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. The use of low solvent or powder coatings 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.

Examples of process changes include:

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

Add-on controls include 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 generally high flow rate of waste gases and the low solvent content, add-on controls are often not the most cost effective abatement option and may be technically complex.

Activity 060109 Other non industrial paint application

Most coatings are applied in-situ, and the only abatement options which may be considered for these coatings are improvements in transfer efficiency and reformulation of coatings. Brush and roller application are widely used and since these methods of application have high transfer efficiencies little further can be done. Where spraying is used there is potential for the use of more efficient systems such as high volume low pressure (HVLP) spraying systems. Reformulation options include high solids and waterborne coatings. Due to the high technical specification of paints used in this sector, there may be problems in using waterborne systems in particular. However, very little information is available on the potential for reductions in solvent emissions from this sector.

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 appropriate emission factor depending on the quality of the coating, the average area of the vehicles, the type of application systems and any control devices fitted. An alternative methodology for wood painting (060107) is to combine the area of coated product with an appropriate emission factor. Emission factors are available for a number of different types of painted wooden products.

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 on SNAP94 060100 level.

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:

(solvent purchased) - (quantifiable solvent output) = 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 (e.g. 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 3.1. 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:

(uncontrolled NMVOC) ´ (1 - control system efficiency) = (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. 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 thining 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 in 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 in terms of paint only, others consider paint to include associated diluents and cleaning solvents as well. The choice of emission factors will depend upon the available activity statistics.

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 painting (060107) 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 waterborne and the mass of organic solventborne 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 all considered point sources.

In addition to this, according to the CORINAIR ‘90 methodology, every plant emitting more than 1,000 Mg/year is a point source. In practice, this is likely to include only a very small number of processes possibly including some coil coating (060105) and wood painting (060107) as well as a very small number of other industrial paint application (060108), principally the painting of metal packaging such as cans.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Table 8.1 - Emission Factors for NMVOCs

Compound	Sectore	Paint type	Abatement type	Abatement efficiency	Fuel type	Emission factor[1]	Data Quality	Country or region	Reference
NMVOC	Car manufacture	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**500 g/kg of paint[2]**	**C**	Unknown	Unknown
NMVOC	Car manufacture	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**675 g/kg of paint[2]**	**C**	UK	Calculated from unpublished UK data
NMVOC	Car manufacture	All types	Solvent management plan / good housekeeping - type controls	30 %	N/A	**473 g/kg of paint[2]**	**D**	UK	Chem Systems Ltd / ERM 1996
NMVOC	Car manufacture	All types	Solvent management plan / good housekeeping - type controls and use of low solvent paints	55 - 60 %	N/A	**270-304 g/kg of paint[2]**	**D**	UK	Chem Systems Ltd / ERM 1996

NMVOC	Vehicle refinishing	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**280 g/kg of paint**	**C**	Unknown	Unknown
NMVOC	Vehicle refinishing	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**600 g/kg of paint (excluding thinners etc)**	**C**	Unknown	Unknown
NMVOC	Vehicle refinishing	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**700 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Vehicle refinishing	All types	Housekeeping - type controls	5 %	N/A	**665 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996
NMVOC	Vehicle refinishing	All types	Housekeeping - type controls, enclosed gunwash and HVLP guns	45 %	N/A	**385 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996
NMVOC	Vehicle refinishing	All types	Housekeeping - type controls, enclosed gunwash and HVLP guns and low solvent paints	60-76 %	N/A	**168-280 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996

NMVOC	Trade decorative	Solventborne	Baseline emission factor (uncontrolled)	N/A	N/A	**300 g/kg of paint**	**C**	Unknown	Unknown
NMVOC	Retail decorative	Solventborne	Baseline emission factor (uncontrolled)	N/A	N/A	**400 g/kg of paint**	**C**	Unknown	Unknown
NMVOC	Decorative	Solventborne	Baseline emission factor (uncontrolled)	N/A	N/A	**300 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data

NMVOC	Decorative	Waterborne	Baseline emission factor (uncontrolled)	N/A	N/A	**33 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996

NMVOC	Coil coating	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**200 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Coil coating	All types	Solvent management plan / good housekeeping - type controls and incineration	95 %	N/A	**10 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996

NMVOC	Boat building	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**750 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Boat building	All types	Improved transfer efficiency and reformulated coatings	55 %	N/A	**338 g/kg of paint**[2]	**E**	UK	Author’s judgement based on information from industry

NMVOC	Wood coating	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**750 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Wood coating	All types	Solvent management plan / good housekeeping - type controls and reformulated paints	74 %	N/A	**270 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996
NMVOC	Wood coating	All types	Solvent management plan / good housekeeping - type controls and add on technology	80 %	N/A	**150 g/kg of paint**[2]	**D**	UK	Chem Systems Ltd / ERM 1996

NMVOC	Other industrial	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**750 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Other industrial	All types	Housekeeping and improved transfer efficiency	35 %	N/A	**488 g/kg of paint**[2]	**E**	UK	Author's judgement
NMVOC	Other industrial	All types	Housekeeping, improved transfer efficiency and reformulated paints	66 %	N/A	**250 g/kg of paint**[2]	**E**	UK	Author's judgement

NMVOC	Other non industrial	All types	Baseline emission factor (uncontrolled)	N/A	N/A	**740 g/kg of paint**[2]	**C**	UK	Calculated from unpublished UK data
NMVOC	Other non industrial	All types	Improved transfer efficiency and reformulated coatings	55 %	N/A	**333 g/kg of paint**[2]	**D**	UK	Author's judgement based on information from industry

Notes:

1. Unless, otherwise stated emission factors are given in terms of emission per kg of paint including thinners and cleaning solvent.
2. These emission factors were originally expressed in g/litre of paint and have been converted to g/kg by assuming that 1 litre of paint weighs 1 kg in the case of wood paints and 1.2kg in the case of all other paints. This is because it is assumed that wood paints are largely unpigmented.

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 characteristic solvent content of the different types of coating used in a country.

An alternative methodology for activity 060101 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 given in terms of the unit painted surface. Table 8.2 summarises the range of emissions observed from small (surface area 65m^2) and large (surface area 117m^2) car painting; these emission factors are for essentially uncontrolled processes.

Table 8.2: 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 8.2, the relevant emission factor must be interpolated. Currently small cars have an average surface of about 65 m^2, medium size cars of about 75 m^2, and large cars of about 90 m^2; the production of these types of cars in the different EC-Member States is shown in Table 8.3.

Table 8.3: 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/m^2 on average for vans, trucks and passenger cars with more than 6 seats (but going up to 0.16 kg/m^2 in some cases);
- 0.5 kg/m^2 for buses.

Possible emission limits (yet to be discussed) are:

- 0.07 kg/m^2 (new plants) and 0.09 kg/m^2 (existing plants) from large installations for vans, trucks and passenger cars with more than 6 seats;
- 0.09 kg/m^2 (new plants) and 0.12 kg/m^2 (existing plants) from small installation for vans, trucks and passenger cars with more than 6 seats produced;
- 0.055 kg/m^2 (new plants) and 0.065 kg/m^2 (existing plants) for truck cabins which are not coated in the same facility as the truck chassis;
- 0.25 kg/m^2 (new plants) and 0.35 kg/m^2 (existing plants) from large installations for buses;
- 0.35 kg/m^2 (new plants) and 0.45 kg/m^2 (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. Estimates of solvent emissions by solvent type reported by selected countries and regions are given in Table 9.1.

Table 9.1. Reported solvent emissions from paint applications per substance group (wt.%).

Country	year	alkanes	aromatics	alcohols	esters	cellosolves	ketones	ClHCs	others
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	-
W.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
Netherlands	1989	30.4	28.5	7.1	9.2	8.2	6.1	3.1	7.5
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
USA	1989	17.1	15.9	16.0	29.8[1]	-	16.5	2.9	1.8

Source: Veldt, 1993

[1]) includes cellosolves
[2]) corrected for aromatics in alkanes

A profile of emissions from the use of paints in the UK is given in Table 9.2.

Table 9.2 Speciated profile of the paint industry in the United Kingdom

Species		wt %
Aliphatic hydrocarbons	white spirit	30.0
	SBP solvents	2.1
Aromatic hydrocarbons	toluene	10.0
	xylenes	12.4
	styrene	2.0
	160-180 boiling fraction	9.2
	180-220 boiling fraction	4.2
Alcohols	ethanol	0.6
	2-propanol	0.8
	2 methyl-1-propanol	1.8
	1-butanol	3.6
	2-butanol	1.5
	4-methyl-4-hydroxy-2-pentanone	1.5
	other alcohols	0.8
Esters	n-butyl acetate	2.7
	ethyl acetate	1.7
	other esters	0.7
Ketones	propanone (acetone)	1.8
	2-butanone (methyl ethyl ketone, MEK)	2.2
	4 methyl-2-pentanone (MIBK)	4.1
	cyclohexanone	0.6
	other ketones	0.6
Glycol ethers/acetates (cellosolves)	2-butoxyethanol	1.4
	1-methoxy-2-propanol	0.8
	other glycol ethers & acetates	1.5
Chlorinated		0.4
Other		1.0

Source: Rudd, 1995

Although data from national speciated surveys can be extrapolated to other countries, a comparison of the estimates from different countries given in Tables 9.1 and 9.2 shows that patterns of solvent use in paints can differ significantly. Countries are therefore encouraged to keep extrapolations at a minimum. These data are generally assigned a data quality B.

10 CURRENT UNCERTAINTY ESTIMATES

Due to the wide range of paint applications and the even larger number of paint formulations which are available, there must be considerable scope for uncertainty in emission factors. Due to developments in paint formulation the emission factors may be valid for only a short period. Improved emission factors are therefore required especially for controlled processes.

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 (i.e. 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 disaggregared 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 vaporisation 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

No supplementary documents are required.

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 8.1.1 in chapter su060000 ‘Solvent use’).

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.

17 REFERENCES

Allemand, N. (1992), Exploratory Study on the Implementation of an EC Policy to Reduce VOC Emissions from the Private Use of Paints and Varnishes and Possible Extension to the Sector of Professional Users for Building Applications, CEC Report EUR 13569 EN.

Aspinwalls & NERA (1995), Evaluating the Costs of Implementing the Proposed EC Solvents Directive and the Scope for Using Economic Instruments

Edwards, A.H. et a., (1985), CONCAWE: Volatile Organic Compound Emissions: An Inventory for Western Europe, Report No. 2/86.

ECE - VOC Task Force (1990), Emissions of Volatile Organic Compounds (VOC) from Stationary Sources and Possibilities of their Control - Final Report, July 1990, Karlsruhe.

EEC (1992), Draft of a Council Directive on the Limitation of Emissions of Organic Solvents from Certain Processes and Industrial Installations, July 1992.

EEC (1993), Proposal for a Council Directive on the Limitation of Emissions of Organic Solvents from Certain Processes and Industrial Installations, XI/835/93 - October 1993.

EPA (1985), Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources, AP-42. Fourth Edition (GPO No. 055-000-00251-7), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, September 1985.

EPA (1990), Air Emission Species Manual Volume I - Volatile organic compound species manual - Second Edition, EPA 450//2-90-01a, January 1990.

ERM Economics & Chem Systems Ltd (1996), Costs and Benefits of the Reduction of VOC Emissions from Industry: Annex on the Costs of Control options for Industry Sectors

Federlegno (1994), Personal Communication

IVECO FIAT (1991), Personal Communication

Macdonald, E.K., Marlow, I.T., Woodfield, J.M. (1991), Control of Emissions of Volatile Organic Compounds from the Large-Scale Varnishing of Car Bodies, CEC Report EUR 13568 EN

OECD (1990), Emissions of Volatile Organic Compounds from Solvent Usage Operations, Environment Monographs No. 23, August 1990, Paris

Obermeier A., Friedrich R., John C., Vob A. (1991), Zeitlicher Verlauf und räumliche Verteilung der Emissionen von fl_chtigen organischen Verbindungen und Kohlenmonoxid in Baden-W_rttenberg, Kernforschungszentrum Karlsruhe, KfK-PEF 78, Februar 78.

Passant, N.R. (1993), Emissions of Volatile Organic Compounds from Stationary Sources in the United Kingdom: a Review of Emission Data by Process, Warren Spring Laboratory, Report No LR990

Richardson S.J., Passant N,R., Woodfield M.J. (1990), The Methodology for the Development of Speciated, Volatile Organic Compound Emission Inventories for Stationary Sources, Paper to EMEP Workshop on Emission Inventory Techniques, Regensburg, Germany, 2-5 July 1991

Rudd, H (1995)., Emissions of Volatile Organic Compounds from Stationary Sources in the United Kingdom: Speciation, AEA Technology, Report No AEA/CS/16419033/REMA-029, National Environmental Technology Centre, Culham Abingdon, Oxfordshire, OX14 3DB, UK

Veldt, C. (1993), VOC: A Little Learning is a Dangerous Thing, TNO/EURASAP workshop on the reliability of VOC emission databases - June 1993, Delft

Zierock, K.-H, 1~(1993), Communication to M. Woodfield.

18 BIBLIOGRAPHY

Adler, P. (1993), Reductions of VOC emissions from painting of car bodies in the Swedish car industry, Swedish Environmental Protection Agency, June 1993.
Loibl, W., Orthofer, R., Winiwarter, W. (1993), Spatially Disaggregated Emission Inventory for Anthropogenic NMVOC in Austria, Atmospheric Environment, 27 A, 2575-2590 (1993).
Malle, B., Hackl, A. (1993), Emission organischer Lösemittel in Österreich - Mengenanalyse and Verminderungspotentiale, Institute f_r Verfahrenstechnik, TU Wien.

19 RELEASE VERSION, DATE AND SOURCE

Version	2.2
Date:	1 February 1999
Updated by	Neil Passant AEA Technology Environment UK
Original author:	Domenico Gaudioso, Silvia Brini, ENEA - Environmental Department Italy

20 POINT OF ENQUIRY

Any comments on this chapter or enquiries should be directed to:

Neil Passant

AEA Technology Environment
Culham
Abingdon
OX14 3ED
UK

Tel: +44 1235 463024
Tel: +44 1235 463005
Email: Neil.Passant@aeat.co.uk