Impact Assessment of Potential Restrictions on the Marketing and Use of Dichloromethane in Paint Strippers

Final Report

prepared for
European Commission
Directorate-General Enterprise and Industry

RPA

April 2007

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European Commission
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by

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RPA REPORT – ASSURED QUALITY	
Project: Ref/Title	J549/DCM
Approach:	In accordance with the Project Specifications and associated discussions with the Client – Incorporates comments from the Commission on the previous version of 22 February 2007
Report Status:	Final Report
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Approved for issue by:	Meg Postle, Director
Date:	26 April 2007

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Full term
ACGIH	American Conference of Governmental Industrial Hygienists
AHP	Analytic Hierarchy Process
AT	Austria
AUTH	Competent Authorities (in European countries)
BAT	Bygge-, Anlægs- og Trækartellet
BE	Belgium
BG	Bulgaria
Carc. Cat.	Carcinogen Category
CAPTV	(French) Centre of Anti-poison and Toxicovigilance
CAS	Chemical Abstracts Service
CBC	Cotton Braided Cable
CCSA	Canadian Centre on Substance Abuse
CEFIC	European Chemical Industry Council
CH	Switzerland
CMC	Composition Materials Company
CNS	Central Nervous System
CO	Carbon monoxide
COHb	Carboxyhaemoglobin (carbon monoxide bound to haemoglobin)
CPSC	United States Consumer Product Safety Commission
CSTEE	EU Scientific Committee on Toxicity, Ecotoxicity and the Environment (now known as SCHER)
CY	Cyprus
CZ	Czech Republic
Danish EPA	Danish Environmental Protection Agency
DBE	Dibasic ester
DCM	Dichloromethane
DE	Germany
DIY	Do-It-Yourself
DK	Denmark
DKK	Danish crown (currency)
DMF	Dimethylformamide
DMSO	Dimethylsulphoxide
DSPA	(US) Dimethyl Sulfoxide Producers Association
EASCR	European Association for Safer Coatings Removal
ECB	European Chemicals Bureau
ECSA	European Chlorinated Solvents Association
EEA	European Economic Area
EE	Estonia
EFPIA	European Federation of Pharmaceutical Industries and Associations
EL	Greece
EPER	European Pollutant Emission Register
EQS	Environmental Quality Standard
ES	Spain

Acronym	**Full term**
ETVAREAD	Expert Team for Vapour Retarding Additives
EU	European Union
EVA	Ethylene vinyl alcohol
FI	Finland
FR	France
HASS/LASS	Home and Leisure Accident Surveillance System
HFC	Hydrofluorocarbon
HU	Hungary
IBC	Intermediate Bulk Container
IE	Ireland
IND	Industry (industrial)
IPPC	Integrated Pollution Prevention and Control
IS	Iceland
ISO	International Standard Organisation
IT	Italy
IUCLID	International Uniform Chemical Information Database
JAIC	Journal of the American Institute for Conservation
LC_{50}	Lethal concentration, 50%
LD_{50}	Lethal dose, 50%
LEV	Local Exhaust Ventilation
LI	Liechtenstein
LOAEL	Lowest observed adverse effect level
LT	Lithuania
LU	Luxembourg
LV	Latvia
MOS	Margin of safety
MT	Malta
NEWMOA	(US) Northeast Waste Management Officials Association
NIOSH	National Institute for Occupational Safety and Health
NL	The Netherlands
NMP	n-methyl-2-pyrrolidone
NO	Norway
NOAEL	No observed adverse effect level
NVR	Non-vapour retarded
OEL	Occupational Exposure Limit
OES	Occupational Exposure Standard
OPRA	Occupational Physicians Reporting Activity (UK)
OSHA	(US) Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PL	Poland
PMB	Plastic media blasting
PPE	Personal protective equipment
PRTR	Pollutant Release and Transfer Register
PT	Portugal
PVA	Polyvinylalcohol
PVC	Polyvinylchloride

Acronym	**Full term**
PVDF	Polyvinylidene fluoride
RAF	Royal Air Force (UK)
Re-Solv	Society for the Prevention of Solvent and Volatile Substance Abuse
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (UK)
RPA	Risk & Policy Analysts Ltd.
SCBA	Self-contained breathing apparatus
SCHER	Scientific Committee on Health and Environmental Risks (previously known as CSTEE)
SE	Sweden
SI	Slovenia
SK	Slovak Republic
SME	Small to Medium Enterprise
SOCMA	(US) Synthetic Organic Chemical Manufacturers Association
SPAB	Society for the Protection of Ancient Buildings
STEL	Short Term Exposure Limit
SWORD	Surveillance of Work-related and Occupational Respiratory Disease (UK)
TGD	Technical Guidance Document
TIS	Technische Informationsstelle des Deutschen Maler- und Lackiererhandwerks
TPF	Traditional Paint Forum
TRGS	Technische Regel für Gefahrstoffe (German Technical Rule for Hazardous Substances)
TWA	Time Weighted Average
UK	United Kingdom
USA	United States of America
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
VR	Vapour-retarded
WFD	Water Framework Directive
WHO	World Health Organization
WSB	Wheat starch blasting
Wt	Weight

EXECUTIVE SUMMARY

1. What is DCM?

Dichloromethane (DCM), also known as methylene chloride, is a colourless, halogenated aliphatic hydrocarbon compound with a penetrating ether-like or mild sweet odour[1]. It is used in:

- the pharmaceutical industry;
- paint stripping;
- aerosols;
- adhesives;
- other applications:

Until recently, there were six manufacturers of DCM in the EU, all of them members of the European Chemical Solvents Association. However, following the expansion of the EU from 25 to 27 Member States on 1 January 2007 (with the accession of Bulgaria and Romania), there is one additional DCM manufacturer (which is not a member of ECSA) located in Romania. Additionally, the Slovenian authorities have suggested that 185 tonnes of DCM are manufactured in Slovenia annually by two companies. The relevant tonnage for these 'extra' three companies has not been accounted for in the data we have received from the six main manufacturers.

The information received to date suggests a total production tonnage of ca. 244,000 tonnes DCM in 2005 of which 132,000 tonnes were sold by the six manufacturers to European customers. The key markets were: pharmaceuticals (by far the largest), solvent and auxiliary applications, paint stripper manufacture and adhesives.

2. Use of DCM in Paint Stripping

Paint strippers are used to remove coats of paints, especially blistered or cracked coats on various substrates, particularly metal and wood. For the purposes of this study, the uses of DCM-based paint strippers have been divided into three categories:

- ***industrial use***: for instance, when DCM-based paint stripper is used in a permanent, stationary technical installation (for instance, metal stripping, furniture stripping, aircraft stripping, etc.);

- ***professional use***: for instance, when DCM-based paint stripper is being used for the removal of paint from exterior and interior walls of buildings, removal of graffiti, removal of paint from doors and window frames by a tradesman (not a consumer) – this use takes place either outdoors (possibly on a scaffold) or at/in the premises of a client; and

[1] A wide range of odour thresholds (530–2,120 mg/m^3) has been reported, but detection occurs around 530 mg/m^3 and recognition around 810 mg/m^3 (WHO, 2000).

- ***consumer use***: for instance, when DCM-based paint stripper is used for DIY activities.

The estimated sales of 'virgin' DCM to paint stripper manufacture are ca. 13,000. The main destinations of paint-stripper related sales of 'virgin' DCM appear to be: France, Germany, Italy, Belgium, the Netherlands, Luxembourg (the last three are considered together), Spain, and the United Kingdom and Ireland (the last two are considered together).

Also a part of 'virgin' sales to the pharmaceuticals industry is recycled (after it has been used as a solvent in the manufacture of pharmaceuticals) and passed on to paint stripper manufacturers. Calculations presented in this report result in an estimated tonnage of DCM used sold for use in paint stripper manufacture in Europe in 2005 of 24,000 tonnes (13,000 tonnes of 'virgin' DCM + 11,000 tonnes recycled/reclaimed DCM).

It is believed that the average DCM-based paint stripper has a concentration of DCM in the range of 60-90%; therefore, the tonnage of DCM-based paint strippers manufactured in Europe in 2005 is estimated to have been 26,700-40,000 tonnes.

3. Human Health Effects of DCM and Morbidity and Mortality Data

The hazard potential of DCM-based paint strippers is not fully apparent from the classification and labelling information. In terms of human toxicology, the hazard potential of DCM lies primarily in its narcotic effect and subsequent depression of the central nervous system (CNS) at high concentrations. The acute toxicity of DCM is low and the most important acute toxic effect is on the CNS and elevated carboxyhaemoglobin (COHb) levels. These effects are reversible, although fatalities have been reported on a number of occasions. The typical effects of high exposure to solvents are often of a neurobehavioral and cardio-toxicological nature. In addition to inhalation, DCM can also be absorbed through the skin and this should be taken into account.

The risks from DCM in paint strippers have been recently assessed in two Commission-funded studied: the TNO report in 1999 and the ETVAREAD report in 2004. Both reports have concluded that further risk reduction measures are required. According to TNO this applies to all three use categories (industrial, professional and consumer use) while ETVAREAD considered that no further measures are required for industrial uses covered by the VOC Directive.

In the course of this study, information has been collected on accidents associated with the consumer, professional and industrial use of DCM-based paint strippers (morbidity data tend to refer to the first two categories of users only). Accident data are presented in Annex E to this report. The available information (collected from industry sources and consultation with Competent Authorities in Member States) is of variable detail with some countries having detailed information while others do not.

According to the available information, DCM-related incidents have resulted in a total of 20 fatalities and 57 non-fatal injuries in Europe. A further 5 fatalities and 15 injuries were also reported for Europe, although detailed information is lacking on these incidents. It is therefore possible that DCM-based paint strippers have been involved in a total of 25 fatalities and 72 non-fatal injuries in Europe to date (1930-2007).

Taking into account only accidents that have occurred in the last 26 years on the assumption that reporting of accidents since 1980 might be more consistent and complete[2] - the total number of (certain) fatalities in the EU is 19 and the number of non-fatal injuries is 45 (i.e. only 1 death and 12 non-fatal injuries occurred before 1980).

With regard to the incidents of unclear relevance to DCM-based paint strippers, since 1980 there have been 5 deaths and 13 non-fatal accidents (i.e. only 2 non-fatal accidents occurred before 1980). In all, since 1980, the total number of deaths and non-fatal accidents may be as high as 24 and 48 respectively (from the available information).

Table 1 below shows the split of these incidents between the three broad use categories of DCM-based paint strippers. The table only presents accidents for which we are verifiably relevant to this study.

Table 1: Overview of Fatalities and Non-Fatal Injuries in Europe (Literature data, 1930-2007)

Use category	**Fatalities**	**Non-fatal injuries**	**Location and time of fatalities**
Industrial use	9	6	FR: 3 (1997, 2002, 2007) DE: 1 (2000) ES: 1 (2000) UK: 4 (1989, 1999x2, 2006)
Professional use	9	26	FR: 2 (1990, 1992) DE: 5 (1989x2, 1990, 1999, 2002) CH: 1 (1996) UK: 1 (2002)
Industrial/Professional use	0	10	
Consumer use	2	14	FR: 1 (1993) NL: 1 (1960)
Totals	**20**	**56**	

2 It is not clear that all accidents relating to DCM-based paint strippers, even since 1980, have definitely been registered and correctly attributed to DCM.

All 20 relevant fatalities in Europe appear to have resulted from one or more of the factors presented in Table 2.

Table 2: Factors Contributing to Fatalities in Accidents involving DCM-based Paint Strippers in Europe (1930 – 2007, accidents of certain relevance to this study).		
Factor potentially contributing to fatality(ies)	**Number of incidents**	**Number of fatalities**
Inadequate ventilation	19	14
Inadequate personal protective equipment	9	9
Use of tanks (occasionally open tanks)	9	9
Heat-related accidents[3]:	2	3
(Possible) alcohol abuse	1	1
Long-term exposure	1	0
Unknown reasons	5	1

These figures are based on the information currently available to us; it is possible that other factors may have played a role in any incident reported in Table E2.1. Moreover, it is generally not possible to indicate which factor was the most 'critical' or 'most important'.

Almost all information on accidents and fatalities (discussed in Section 3 and Annex E) has been provided by third parties and open literature. We are not able to guarantee the accuracy and interpretations of this data as it has not been possible to independently verify all sources during the course of this study.

4. Need for Further Risk Reduction Measures

The assessment of the effectiveness of existing risk reduction measures has taken into account:

- the results of the two **previous assessment reports** on DCM in paint strippers (TNO, 1999 and ETVAREAD, 2004);
- the available information on **exposure levels** during use (Annex D);
- the existing **legislation** at the EU and national level (Section 4);
- the available information on **current practices** among users (Section 4);
- the available information on relevant **accidents** (Annex E); and
- the **views of stakeholders**.

On the basis of the analysis undertaken for each of the points above, it is concluded that further risk reduction measures are necessary to prevent accidents that result in fatalities and injuries among the users of these formulations and to protect the health of the users.

3 The report on the fatal accident in Switzerland in 1996 mentions that the accident took place in a closed space on a warm day, however, weather conditions were not included in the possible reasons for the accident. The 3 deaths mentioned in the bulletpoint above do not include that fatality.

The key issues identified for each use category which are discussed in detail in Sections 4 and 7 are:

For industrial uses:

- the effectiveness of existing controls and prevalence of (often fatal) accidents frequently linked to poor ventilation, use of inappropriate Personal Protective Equipment or (open) dipping tanks; and
- the enforcement and compliance shortcomings of the current legislative framework.

For professional uses:

- the effectiveness of existing controls and their practical implementation (with an emphasis on Occupational Exposure Limits);
- the inappropriate use of Personal Protective Equipment;
- the mobile nature of the sector and the large number of SMEs and micro-enterprises; and
- the occasional consumer-like perception of risks.

For consumer uses:

- the inherent problems of monitoring and controlling consumers' behaviour when using DCM-based paint strippers; and
- the paucity of appropriate health and safety information, available to consumers who use the exact same products as used by professional uses (for which an assessment of risks and appropriate risk management measures is required by law).

5. Availability and Suitability of Alternatives

Regardless of use category (whether consumer, professional or industrial), there are three basic methods of paint stripping:

- physical/mechanical stripping;
- pyrolytic/thermal stripping; and
- chemical stripping.

We have examined all three categories in Section 5 to this report. With particular regard to chemical stripping, the following chemical substances which can act as replacement 'active' substances in paint stripping formulations were examined in further detail:

- n-methyl-2-pyrrolidone (CAS No. 872-50-4);
- benzyl alcohol (CAS No. 100-51-6);
- dimethyl sulphoxide (CAS No. 67-68-5);
- 1,3-dioxolane (CAS No. 646-06-0);
- sodium hydroxide (CAS No. 1310-73-2); and

- dibasic esters (CAS Nos. 106-65-0, 1119-40-0, 627-93-0, and (95481-62-2 (the last one– this is the CAS Number for the mixture of the three individual dibasic esters)).

The analysis in Section 5 suggests the following:

Technical suitability of alternatives:

(a) technically suitable alternatives to DCM-based paint strippers are generally available on the market;

(b) it is neither possible nor feasible to select a specific substance or technique as being the most appropriate for paint stripping. This is because each of the paint stripping formulations and techniques considered has unique advantages and disadvantages;

(c) the performance of a paint stripper also depends on the experience and competence of the formulator and on whether the user is able and/or willing to follow the instructions of each paint-stripping method;

(d) for some applications, the introduction of an alternative substance or technique (as a result of any restrictions) may be simple and 'seamless', while for other applications, it may be more complicated (time delay issues have particularly been highlighted by some consultees, especially when 'small' quick jobs need to be undertaken);

(e) in the event of a restriction on DCM-based paint strippers, users would need to undertake a more detailed assessment of the task at hand and of what the necessary stripping materials should be. This would require more focus and knowledge from the user and, it can be argued, would raise the standards in the industry; and

(f) the real-life example of Austria, Denmark and Sweden, where the use of DCM-based paint strippers is already restricted, suggests substitution of these products is feasible. An EU-wide restriction would have the added benefit of harmonising the internal market

Risks to human health and the environment from alternatives:

(a) in terms of risks to human health and the environment, each paint stripping method may have effects on human health and the environment. In fact, not all alternative paint strippers can be considered as safer than DCM-based paint strippers;

(b) alternatives should be used with a proper assessment of the risks and with the appropriate engineering controls and PPE;

(c) it may be argued that DCM has a unique profile of adverse effects to human health coupled with being a priority substance under the Water Framework Directive. Also, because of its high concentration in paint stripping products, its high volatility and narcotic effects, DCM poses a direct risk of death as a result of misuse (a characteristic not necessarily shared by most of the alternatives). On balance, there are alternatives with a much better human health and environmental hazard and risk profile.

It should be noted that the analysis in Section 5 focuses on a selection of 'active' substances without addressing the potential hazards to human health and the environment from all components of alternative formulations (or the remaining components of DCM-based paint strippers for that matter).

Cost of alternatives: the cost per kilogram of a product is far from an adequate indicator of its overall cost. The 'real' cost of a paint stripping formulation/method involves the cost of the material or equipment, the time required for a job to finish, the quantity of paint stripper required per square metre of stripped surface, the cost of purchasing, using and replacing promptly the required (forced) ventilation equipment and PPE and the cost of disposing of any generated waste during the stripping operation. When these factors are taken into account, alternatives may not be as costly as DCM-based paint strippers (when the latter are used in the appropriate manner and with the necessary risk management measures are in place).

6. Risk Reduction Measures under Consideration

We have considered a range of potential risk reduction measures for industrial, professional and consumer uses. These are presented in Tables 3 and 4, below with each one numbered to facilitate discussion and analysis in the report.

Table 3: Potential Risk Reduction Measures for Industrial and Professional Uses of DCM-based Paint Strippers

Restrictive measures	
A1. Total prohibition (ban) on all industrial uses of DCM-based paint strippers.	B1. Total prohibition (ban) on all professional uses of DCM-based paint strippers.
A2. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless used in strictly controlled conditions A3. Prohibition (ban) on all industrial uses of DCM-based paint strippers in enclosed spaces	B2. Prohibition (ban) on all professional uses of DCM-based paint strippers unless used in strictly controlled conditions B3. Prohibition (ban) on professional use of DCM-based paint strippers in enclosed spaces.
A4. Prohibition (ban) of all industrial uses of DCM-based paint strippers unless appropriate personal protective equipment is used.	B4. Prohibition (ban) of all professional uses of DCM-based paint strippers unless appropriate personal protective equipment is used.
A5. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two possible thresholds*).	B5. Prohibition (ban) on all professional uses of DCM-based paint strippers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two possible thresholds*).

Table 3: Potential Risk Reduction Measures for Industrial and Professional Uses of DCM-based Paint Strippers	
A6. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (*possible thresholds: 5,000 ml or 1,000 ml*).	B6. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (possible thresholds: 5,000 ml, 1,000 ml or 500 ml) by a qualified licensed tradesman.
A7. Prohibition (ban) on the use of DCM-based paint strippers unless used by a qualified licensed (industrial) user.	B7. Prohibition (ban) on the use of DCM-based paint strippers unless used by a qualified licensed (professional) user
Non-restrictive measures	
A8. Establishment of a Community-wide occupational exposure limit for DCM.	B8. Establishment of a Community-wide occupational exposure limit for DCM.
A9. Provision of additional information (in addition to what is provided for by the Classification and Labelling legislation in Safety Data Sheets) on using DCM-based paint strippers under conditions of adequate ventilation.	B9. Provision of additional information (in addition to what is provided for by the Classification and Labelling legislation in Safety Data Sheets) on using DCM-based paint strippers under conditions of adequate ventilation.
A10. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.	B10. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.
A11. Provision of training to users involved in industrial uses to ensure that DCM-based paint strippers are used with appropriate personal protective equipment and conditions of ventilation as well as provision of instructions on appropriate emergency action.	B11. Provision of training to users involved in professional uses to ensure that DCM-based paint strippers are used with appropriate personal protective equipment and conditions of ventilation as well as provision of instructions on appropriate emergency action.

Table 4: Potential Risk Reduction Measures for Consumer Uses of DCM-based Paint Strippers
Restrictive measures
C1. Total prohibition (ban) on all consumer uses of DCM-based paint strippers.
C2. Prohibition (ban) of self-service sale of DCM-based paint strippers.
C3. Prohibition (ban) on consumer use of DCM-based paint strippers in enclosed spaces (for example, basements, small rooms without windows, etc.).
C4. Prohibition (ban) of sales of DCM-based paint strippers unless sold along with appropriate personal protective equipment.
C5. Prohibition on sales of DCM-based paint strippers to consumers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two threshold values*).
Non-restrictive measures
C6. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (*possible thresholds: 500 ml or 1,000 ml*).
C7. Provision of additional information (on containers or accompanying technical literature) on using DCM-based paint strippers under conditions of adequate ventilation (i.e. clear warnings on containers restricting the use of DCM-based paint strippers in closed spaces or without adequate ventilation).
C8. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.

7. Economic Impact of Potential Restrictions

Potential impacts of restrictions on manufacturers of DCM and paint strippers

Manufacturers of DCM are likely to incur two main costs:

- ***lost profits from lost sales***: the decrease in revenues from the loss of sales is estimated at around €13 million per year, with this translating to actual losses in profits ranging from between €1.3 million to €3.2 million per year. Taking a 33% split between industrial, professional and consumer uses, the lost profits per use category would be between **€430,000 and €1.1 million per year per use category**; and

- ***losses relating to a potential price drop***: estimated at around €9.8 million per year for the European market or €23 million for the global market, depending on which markets will be affected. Again, taking a 33% split between industrial, professional and consumer uses, the lost revenue (assumed here to reflect decreases in profit margins) per use category restricted will be from around **€3.3 million** up to **€7.7 million per year per use category for European or global sales respectively.**

It should also be noted that, more generally, sales of DCM for the manufacture of paint stripping account for only a small part of the total DCM sales for the manufacturers. Moreover, sales of 'virgin' DCM (and particularly sales to paint stripper manufacturers) have been steadily diminishing over the last 10 years.

The six manufacturers of DCM are very likely to compensate part of their losses from increased sales of ingredients for alternative paint strippers (such as DMSO and sodium hydroxide). The extent of these benefits cannot, however, be accurately predicted or quantified at present.

For manufacturers of DCM-based paint strippers, the economic impacts of a restriction are unlikely to be as high as those described by (the UK) industry, since alternative formulations are already available and several of the manufacturers of DCM-based paint strippers already offer them. While there might be an increase in raw material costs and a need for some alterations to their production facilities, the likely benefits from a restriction should offset to some extent the likely costs.

Companies involved in industrial uses of DCM-based paint strippers

A restriction on the marketing and use of DCM-based paint strippers is likely to have an impact on many companies involved in industrial uses, particularly with regard to: (a) the increased cost of alternative chemical preparations and (b) the capital costs of adapting existing installations for use with the alternatives. These costs could indeed be significant, especially for SMEs working with low profit margins. Other potential costs include the costs of an increase in the duration of the operations and the need to heat the dip tanks with some alternatives (wherever a tank dip system is operated).

All of these costs will at least be partly offset by the benefits expected for users in terms of reduced costs of waste treatment (although not in every case), reduced costs for ventilation, reduced costs of PPE and reduced insurance premiums. An example of a furniture stripping business shows that after an initial capital investment of £3,000 (1992 prices) for new equipment and an initial cost for filling the strip tank, the operating costs of the company were reduced by around 35% after switching to a DCM-free alternative.

Companies involved in professional uses of DCM-based paint strippers

A generic case study presented in Section 8 suggests that, following a restriction on the marketing and use of DCM-based paint strippers, the use of alternatives may be accompanied by net savings. This may not be obvious to users involved in professional uses at present since they are accustomed to using DCM-based products without a proper assessment of the risks and, it would appear, without the PPE that is appropriate to the chemical and its hazards. The savings arising from switching to alternatives could prove to be very significant, particularly in paint stripping operations where engineering controls are inadequate and self-contained breathing masks with air supply should be used.

There may be issues arising from the slower action of alternatives which means that operations may take additional time to complete and that the user needs to change his habits and patterns of work (so as to minimise losses from idle time). Companies with larger operations may be more able to accommodate such changes and absorb any ensuing costs than smaller businesses. It is more likely that smaller businesses rely on the quick completion of small tasks, and their ability to do so may be considerably affected if the alternatives that work well are slow acting formulations.

Consumer uses of DCM-based paint strippers

Following from the assessment of costs and benefits, and from a purely financial point of view, restrictions on the marketing and use of DCM-based paint strippers are unlikely to be financially damaging to the consumer. A generic case study is presented in Section 8; this suggests that when DCM-based paint strippers are used with the appropriate risk management measures (which at present is not the case), these formulations have a higher cost to the consumer, even when the alternative paint strippers act more slowly.

Conclusions on impacts of restrictions on other stakeholders/third parties

In terms of costs, some impacts (particularly, relating to inconvenience) may be expected on distributors. However, little information or indication of such impacts has been provided and it may be assumed that they are unlikely to be significant.

Manufacturers and suppliers of (other) components of DCM-based formulations (e.g. methanol) may also be affected by any restrictions. Since the total weight of this large variety of components tends to make up only 10-40% of the DCM formulation and these substances may also be used as components of alternative paint stripping formulations, the impacts are unlikely to be damaging in the medium to long term.

Furthermore, a restriction on DCM-based paint strippers would potentially open up a market of several thousand tonnes of solvents per year to be utilised in the manufacture of alternative formulations. This would create new business for those companies producing these solvents (and DCM manufacturers and manufactures of DCM-based paint strippers could well be among them). There is insufficient information on which to provide meaningful quantitative estimates of the likely benefits to these stakeholders from a restriction on the marketing and use of DCM-based paint strippers. However, a quick calculation of the size of the new market for alternatives presented in Section 8 suggests that this could be as high as €240 million.

8. Recommended Further Risk Reduction Measure and Justification

Recommended Risk Reduction Measure

The recommended risk reduction measure is set as follows:

Recommendation

To consider at Community level, marketing and use restrictions under Council Directive 76/769/EEC (Marketing and Use Directive) on **all uses of DCM-based paint strippers, unless used in industrial installations under strictly controlled conditions**. The strictly controlled conditions require that:

a) fluororubber gloves must be used during all paint stripping activities;

b) effective local exhaust ventilation and mechanical ventilation (e.g. a fan) should be installed to provide make up air (where this takes into account, existing occupational exposure limits under Directive 98/24/EC) OR an independent air supply respiratory equipment must be worn at all times; and

c) the sides and top of all dip tanks should be enclosed and a separate ventilated area provided for drying finished articles.

Notes:

a) *Industrial installation refers to a permanent stationary technical unit where paint stripping activities are undertaken (for instance, metal stripping, furniture stripping, aircraft stripping, etc.). This term includes factories, workshops and other similar installations.*

b) *Section 4.9 of this report has discussed at length the issue of gloves. Although there is limited doubt that fluororubber gloves offer the best possible protection when using DCM-based paint strippers, there is an issue regarding the rate of replacement of the gloves. While laboratory tests indicate a breakthrough time of 150 minutes, this period may not be the most appropriate for setting a legislative requirement for periodic glove replacement. Factors that need to be accounted for include the nature and duration of paint stripping operations, the mechanical stress during use, the effect of sweat and the behaviour of the user. As shown in Section 4.9.5, it is not possible to specify a replacement rate for gloves used with DCM-based paint strippers. The employers should contact their glove suppliers to inform them of their working practices and the composition of the formulations they intend to use, and to obtain advice on the rate at which the gloves should be replaced.*

c) *Independent air supply respirator is a breathing apparatus that provides breathing air from a source independent of the surrounding atmosphere used (e.g. fresh-air or compressed-air equipment).*

Summary Justification for Recommended Risk Reduction Measures

Industrial Uses

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) were as follows:

A1. Total prohibition (ban) on all industrial uses of DCM-based paint strippers.

A2. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless used in strictly controlled conditions.

A4. Prohibition (ban) of all industrial uses of DCM-based paint strippers unless appropriate personal protective equipment is used.

Our recommendation is based on Measure A2 for the following reasons.

The available information on accidents involving the use of DCM-based paint strippers suggests that most fatalities in Europe have occurred in industrial settings, with **poor ventilation** and the **use of (open) dip tanks** as a recurring feature of these accidents. Any recommended risk reduction measure should aim at ensuring a reduction in such DCM-related incidents.

Taking into account, (a) the potentially significant socio-economic impacts (particularly for SMEs) of an abrupt and total restriction on industrial uses of DCM-based paint strippers; and (b) the existing worker and environmental protection legislation (including legislation in the pipeline (e.g. REACH), it is considered that ensuring industrial use of DCM-based paint strippers under "*strictly controlled conditions*" (Measure A2) should be sufficient for minimising the relevant risks. The existing legislative framework and the stationary nature of the operations mean that there can be a reasonable degree of confidence that the implementation and monitoring of the strictly controlled conditions of operation will be successful. Moreover, companies involved in industrial uses may be better positioned to successfully address issues of health and safety of employees in comparison to other users.

Professional Uses

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) as follows:

B1. Total prohibition (ban) on all professional uses of DCM-based paint strippers.

B2. Prohibition (ban) on all professional uses of DCM-based paint strippers unless used in strictly controlled conditions.

B4. Prohibition (ban) of all professional uses of DCM-based paint strippers unless appropriate personal protective equipment is used.

Our recommendation is based on Measure B1 for the following reasons.

The analysis undertaken for this study indicates that there is great variability in risk management practices during professional use of DCM-based paint strippers. Consultation with various stakeholders has highlighted a number of key issues.

- ***Lack of enforcement***: current enforcement practices are inherently inadequate, especially due to the large number, small size and mobile nature of the enterprises involved (where these enterprises are often individuals who work alone and/or are self-employed). The actual relevance of OELs to those using DCM-based paint strippers in professional uses is also limited (due to their widely varying working conditions) and the ability of users to measure the exposure levels is practically non-existent. More significantly, competent authorities do not appear to have the human and financial resources required (nor make it a priority) to monitor such uses. As a result, implementation and monitoring of a measure such as Measure B4 would probably add very little to the current situation and its monitoring would be very difficult.

- ***Non-compliance with legislation***: the users' knowledge of how to properly assess the risks (as required under Directive 98/24/EC) before using DCM-based paint strippers is limited and patchy. Consultation with companies involved in professional uses indicates that risk assessments are hardly undertaken for jobs that are considered 'small and quick'. In addition, most SMEs are unlikely to employ a dedicated health and safety manager. Only larger companies (for instance, companies sub-contracted to large public sector organisations, engineering companies with their own Health & Safety divisions, etc.) may be more inclined (or required), well equipped and knowledgeable to undertake a proper evaluation of the risks at all times as issues of liability and insurance are (more) important.

- ***Ignorance regarding appropriate risk management***: the use of engineering controls and especially PPE is very often inappropriate and inadequate. It is unlikely that the appropriate engineering controls would be used in the absence of a proper risk assessment (although, admittedly, in some cases it may be immediately clear whether engineering controls are needed and what these should be). While there are several types of gloves being used by those involved in professional uses, there is little evidence of the actual use of fluororubber gloves (which are generally considered to the most appropriate for the identified risks). Another example can be found in the use of visors for the protection of the operator's face. These offer limited respiratory protection and the visors are occasionally removed by operators because they are uncomfortable[4].

  Risk management practices are also hindered by inconsistencies in the information provided by suppliers. There appears to be no consensus amongst manufacturers,

4 Consultation indicates that professional users sometimes find the lack (or non-use) of a mask as a better risk management measure because this allows them to smell DCM in the air and be alerted to high concentrations. This practice does not, however, reflect the fact that DCM only becomes detectable to the human nose at concentrations well above the highest established national OELs.

authorities and users across the EU regarding what gloves and respiratory equipment may be appropriate and for how long. Hence, users are in general not provided with accurate, harmonised and/or up-to-date information on the hazards, risks and appropriate risk reduction measures (especially PPE) when working with DCM-based paint strippers.

- ***Poor risk perception***: Many users may only undertake occasional paint stripping work and they may purchase their materials from a DIY retail outlet as a consumer. This has two key implications: (a) these professional users have access to the same level of (limited) information (and safety requirements) as the consumer, and (b) the purchase of DCM-based paint strippers alongside consumers undermines the perception of risk when using the same product in the workplace. Also, those involved in professional uses tend to rely on their 'long working experience' with DCM-based paint strippers as evidence for knowledge of risks.

- ***Market issues***: it is generally difficult (if not, impossible) to distinguish between consumers and professionals at the point of sale. Therefore, any measures (particularly restrictions) applied to consumers should also ideally apply to those involved in professional uses for practical and enforcement reasons.

We have considered whether a measure such as Measure B2 would be an appropriate option for risk management. Our conclusion is that, overall, requiring the professional use of DCM-based paint strippers to take place only under *strictly controlled conditions* would be impractical and unrealistic for the following reasons:

- measures relating to dip tanks are of no relevance to professional uses;

- ensuring that there is "effective" ventilation is impractical since, for professional uses, employees usually do not have the knowledge and/or the necessary equipment to achieve that (or to measure compliance against OELs);

- the use of fluororubber gloves (as well as independent air-supply respirators) for several of the delicate applications that a decorator may undertake could make the use of the paint stripper very uncomfortable and difficult. More generally, it is unrealistic (taking into account the profit margins for these companies) to expect that users would be willing to use independent air-supply respirators and thick fluororubber gloves, as required by the proposed restrictions;
- as indicated earlier, the vast majority of companies involved are SMEs, and may in fact be micro-enterprises, which are very unlikely to employ a Health and Safety expert who might be able to provide appropriate and consistent advice and to monitor closely the practices of other employees; and

- the mobile nature of professional uses provides little reassurance for effective monitoring and enforcement of such strictly controlled conditions.

As a result of the above, and taking into consideration the analysis of the costs of a restriction as outlined in Section 8, Measure B1 (total ban on professional uses of DCM-based paint strippers) is considered to be the most appropriate option.

<u>Consumer Uses</u>

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) were the following:

C1. Total prohibition on all consumer uses of DCM-based paint strippers

C4. Prohibition on sales of DCM-based paint strippers unless sold along with appropriate PPE

Our recommendation is based on Measure C1 for the reasons that follow.

Consumers are offered and use the same DCM-based product as the companies involved in professional uses, however:

- they are not provided with the same amount of information and/or training (which, in any case, is currently inadequate);
- they are not subject to the same regulatory requirements, inspections or reporting requirements (in cases of accidents) and are, in particular, not required to undertake a proper evaluation of the risks (which, in any case, they are not best placed to undertake);
- they do not have access to the same equipment (especially engineering controls) as users involved in professional uses. In some cases, the working conditions at home may be much worse than those for tradesmen (for example, paint stripping may be undertaken in a basement, or an enclosed area with closed windows, due to bad weather, or in the presence of vulnerable persons such as children, elderly relatives or those with health conditions); and
- the correct PPE is disproportionately costly for consumers (and as, such, despite its advantages, it is not possible to recommend a prohibition on sales of DCM-based paint strippers unless sold along with appropriate PPE). In addition, authorities would not be able to enforce restrictions on consumers.

As a result of the above, and taking into account the fact that alternatives are available and their use is likely to result in small if any economic impact to the consumer (see analysis in Section 8.6), our recommendation is that the consumer uses of DCM-based paint strippers are banned.

1. INTRODUCTION

1.1 Introduction to Dichloromethane (DCM)

Dichloromethane (DCM), also known as methylene chloride, is a colourless, halogenated aliphatic hydrocarbon compound with a penetrating ether-like or mild sweet odour[5]. It is produced (together with other chloromethanes, e.g. chloroform) mainly from methanol, methane and chlorine and is completely miscible with most organic solvents (e.g. ethanol, phenols and aldehydes). It is sparingly soluble in water, normally stable, non-flammable and non-explosive when mixed with air (although temperatures above 100°C should be avoided). DCM's evaporation rate is 27.5 (reference liquid is butyl acetate = 1)[6] and its vapours are heavier than air (WHO, 2000).

Table 1.1 summarises the key physicochemical properties of DCM.

Table 1.1: Identity of DCM	
Property	**Value**
EINECS Name	Dichloromethane
EINECS/EC No.	200-838-9
CAS number	75-09-2
Synonyms	Methylene chloride, methylene dichloride
Molecular formula	CH_2Cl_2
Structural formula	
Molecular weight	84.9
Physicochemical Properties	
Physical state at 20°C and 101.3 KPa	Liquid
Melting point	-96.7 to -94°C
Boiling point	30 to 40°C
Decomposition temperature	120°C
Relative density	1.33 g/cm^3
Vapour pressure	465 to 475 hPa at 20°C
Water solubility	13.7 to 20 g/lit at 20°C
Solubility of DCM in water***	1.3702 wt%
Solubility of water in DCM***	0.1599 wt%
Partition coefficient n-octanol/water (log value)	1.25 at 25°C

5 A wide range of odour thresholds (530–2,120 mg/m^3) has been reported, but detection occurs around 530 mg/m^3 and recognition around 810 mg/m^3 (WHO, 2000).

6 According to the Internet site of a manufacturer, the evaporation rate of DCM is 7 in respect to the evaporation rate of n-butyl acetate which is assumed to have an evaporation rate of 1, when measured in accordance with method ASTM D3539-76 (Dow, 2007b).

Table 1.1: Identity of DCM

Property	**Value**
Flash point/ Flammability/Explosive properties	Not flammable - Flammable limits (at 25°C) 14 % -22 % solvent in air** Not explosive
Self-ignition temperature	605 to 650°C
Viscosity	Dynamic viscosity: 0.43 mPa at 20°C *
Conversion factors	1 mg/m^3 = 0.28 ppm 1 ppm = 3.53 mg/m^3

*Sources: IUCLID data sheet dated 19 February 2000; ECB Internet site (ecb.jrc.it/esis/); ICSC, 2000; *Euro Chlor, 1999; ** HSIA, 2003 and ***Dow, 2007a*

Table 1.2 summarises the current classification and labelling for DCM in accordance with Annex I of Directive 67/548/EEC.

Table 1.2: Classification and Labelling for DCM

Annex I Index Number	602-004-00-3
Substance name in Annex I	EN: Dichloromethane, Methylene chloride DK: Dichlormethan, Methylenchlorid DE: Dichlormethan, Methylenchlorid EL: Διχλωρομεθάνιο, Μεθυλενοδιχλωρίδιο ES: Diclorometano, Cloruro de metileno FI: Metyleenikloridi FR: Dichlorométhane, Chlorure de méthylène IT: Diclorometano, Cloruro di metilene NL: Methyleenchloride PL: Dichlorometan, Dichlorek metylenu, Chlorek metylenu PT: Diclorometano, Cloreto de metileno SV: Diklormetan, Metylenklorid
ATP (Adaptation to Technical Progress)	19th (inserted)
Classification	Carc. Cat. 3
Risk phrases	**R40**: Limited evidence of a carcinogenic effect
Safety phrases	**S2**: Keep out of the reach of children **S23**: Do not breathe gas/fumes/vapour/spray (appropriate wording to be specified by the manufacturer) **S24/25**: Avoid contact with skin and eyes **S36/37**: Wear suitable protective clothing and gloves
Symbol(s) and indication(s) of danger	**Xn**: Harmful 

Source: ECB Internet site (ecb.jrc.it/esis/)

Table 1.3 summarises the available information on the key human health and environmental endpoints for DCM.

Table 1.3: Human Health and Environmental Effects of DCM	
Human Health Endpoints	
Skin Irritation	Irritating (rabbit)
Eye Irritation	Slightly irritating (rabbit)
Skin Sensitisation	Not sensitising (human)
Mutagenicity	*in vitro*: mammalian cell: negative; Ames test: positive *in vivo*: inconclusive
Acute Toxicity	Oral: LD_{50} 1,410 - 2,524 mg/kg (rat) Inhalation: LC_{50} 49,000– 78,000 mg/m^3 (mouse and rat) Dermal: LD_{50} >2,000 mg/kg bw (rat)
Repeated Dose Toxicity	Oral: liver/kidney damage reported Inhalation: adverse effects on CNS, cardiac injury, heart failure and death
Reproductive Toxicity	No reprotoxic effects reported
Carcinogenicity	Currently classified as Carc. Cat. 3.
Environmental Endpoints	
Persistence and Degradation	Not readily biodegradable (5-26% after 28 days)
Bioconcentration	Not expected to bioaccumulate
Aquatic Toxicity*	Fish: 96h-LC_{50} = 193 mg/l Daphnia: 48h-EC_{50} = 135 – 220 mg/l Algae: 96h-IC_{50} > 660 mg/l
** With regard to aquatic toxicity, information from Euro Chlor (1999) concluded a Predicted No Effect Concentration of 830 µg/l on the basis of a chronic study*	

1.2 Uses and Applications of DCM

'Virgin', as opposed to recycled DCM, would usually be amylene-stabilised. Amylene 'mops up' stray chloride ions (formed from the fragmentation of DCM molecules) which if left unchecked, attach themselves to any available traces of moisture to form hydrochloric acid. The hydrochloric acid may then lead to in-can corrosion or localised corrosion in the case of big vats of product in a factory

DCM has found widespread applications in many industrial fields due to its properties, which include (LII Europe, 2002):

- very high solvency power;
- evenly boiling mono component (no solvent combination);
- low boiling, easily removable;
- easy and cost efficient recycling;
- no enrichment in the environment;
- no ozone depletion potential; and
- negligible effect to global warming and smog creation.

Its uses include (Euro Chlor, 1999):

- ***in the pharmaceutical industry***: DCM is used as a solvent for chemical reactions, purification and isolation of intermediates or products;
- ***in paint stripping***: DCM-based paint strippers (normally consisting of 60-90% DCM[7] along with other organic solvents, surfactants, emulsifiers and alkaline and/or acid activators) are used for coating removal;
- ***in aerosols***: DCM has been used since the mid-1970 to replace chlorofluorocarbons (not as a propellant itself), to contribute to improved homogeneity through its good solvency, and to reduce the flammability of the propellant hydrocarbon mixture. Relevant applications include aerosol cans (sprays) for insecticides, lacquers, varnishes and cold cleaners and industrial technical uses like mould release agents and cleansers (LII Europe, 2002);
- ***in adhesives***: DCM acts as a replacement for 1,1,1-trichloroethane; and
- ***in other applications***: these may include (LII Europe, 2002):
    - food processing (solvent in natural product processing, mainly extraction of flavours, aromas, vegetable and animal oils, cacao butter, etc. and for the decaffeination of unroasted coffee beans);
    - metal degreasing (solvent for metal degreasing and cleaning (`surface treatment´) in the metal and electronic industry (either by hot vapour degreasing or by cold dipping);
    - foam blowing (for polyurethanes and in the cleaning of injection moulds);
    - chemical processing (polyurethanes (swelling agent or adhesive for plastic mouldings, polyurethane and polystyrene foams, especially for seamless mattresses and upholstery), polycarbonates, cellulose triacetate (for photographic films, textiles and cigarette-filter tows));
    - as secondary refrigerant medium (the feed-stock for difluoromethane (R 32, HFC 32) which is used as environmentally friendly refrigerant in mixtures like R 407c and R 410a to substitute the damaging chlorofluorocarbons);
    - as thinner for bitumen to impregnate constructions and wood, ingredient of adhesives for artificial leather, shoe repairing and road paints;
    - refining of montan wax etc. and for degreasing of raw fur;

[7] Euro Chlor (1999) suggests a range of 70-90%. Later in this report, we refer to information from manufacturers of DCM-based paint strippers which shows that the concentration of DCM may be significantly lower than 70%. Our conclusion is that a range of 60-90% is rather more representative of the wide range of products available on the EU market and this is the range used in the text above.

- as cooling liquid e.g. for low-temperature reactions; and
- as chemical laboratory agent (for chemical synthesis, extractions and analysis).

Other minor uses identified through consultation include: asphalt testing; carpet adhesive removers; PVC recovery agent; de-paraffination of oil and pyrotechnics. This information is invariably based on information passed on to manufacturers of DCM by their customers or traders.

Some of these applications/uses may be historic in Europe. For instance, while one DCM manufacturer suggested that the substance may be used in textile cleaning, literature by another manufacturer notes that DCM is not suited for cleaning purposes of clothes and textiles. The substance swells or dissolves many polymer fibres, knobs, and accessories, in particular materials made of acetate rayon, polyesters and polyacrylonitrile. Similarly, one manufacturer notes that uses in coatings (and also in detergents/dry cleaning) are not relevant; however, another indicates sales to coatings manufacturers (but this could simply relate to use in the manufacture of paint strippers by the coatings manufacturers).

1.3 Use of DCM in Paint Stripping

Paint strippers are used in industrial, professional and consumer (do-it-yourself (DIY)) environments to remove coats of paints, especially blistered or cracked coats on various substrates, particularly metal and wood. DCM is claimed to be one of the most powerful paint stripper solvents in common use and this use constitutes the focus of this study.

For the purposes of this study, the uses of DCM-based paint strippers have been divided into three categories:

- ***industrial use***: for instance, when DCM-based paint stripper is used in an stationary technical installation (for instance, metal stripping, furniture stripping, aircraft stripping, etc.);
- ***professional use***: for instance, when DCM-based paint stripper is being used for the removal of paint from exterior and interior walls of buildings, removal of graffiti, removal of paint from doors and window frames by a tradesman (not a consumer) – this use takes place either outdoors (possibly on a scaffold) or at/in the premises of a client; and
- ***consumer use***: for instance, when DCM-based paint stripper is used for DIY activities.

In this report, we have avoided, where possible and appropriate, to make reference to industrial, professional and consumer users and rather focus on industrial, professional and consumer uses. This is due to the fact that one user may have more than one capacity; for instance, a user may visit clients to remove paints from doors (i.e. he acts as a professional stripper) and he may also own and operate a stationary workshop in which he may be stripping doors in a dipping tank (thee may be delivered to him by his clients). Although DCM is particularly effective at removing paint coats from substrates, DCM has been under regulatory debate for a number of years with differing views on health effects, performance and the need for risk reduction measures. In particular, because DCM shows high volatility, paint stripping operations involving DCM-based formulations often result in significant releases of DCM and, potentially, exposure of the user to the substance. Accidents involving both occupational and consumer users of paint strippers containing DCM have also been reported – this has further heightened the debate.

To address the issues relating to DCM, the Commission organised a Stakeholders Forum on 14 November 2005 in Brussels to allow for formulators and downstream users to express their views and for more information on product availability within the EU market to be collected. The discussions at the Forum highlighted the fact that there are varying standpoints among different players in the EU market and as a result, no firm conclusion was reached. The Commission has thus commissioned Risk & Policy Analysts Ltd. (RPA) to undertake a study to clarify some of the key issues relating to the use of DCM and the attendant risks and to gather more information and data at European level from all the Member States.

1.4 Objectives of the Study and Organisation of this Report

The objectives of this study are as follows:

- the completion of the available information on the current uses of DCM in paint strippers in all use environments (consumer DIY uses, professional uses and industry uses);
- the completion of the available information on the problems to human health from the use of DCM-based paint strippers;
- the identification of alternatives and the assessment of their risks and benefits;
- the analysis of existing national restrictions and the identification of possible risk reduction options; and
- the assessment of risk management options to appraise their potential health, environmental and economic impacts.

This Final Report presents a summary of the work undertaken to date by RPA in order to achieve the study objectives and takes into account the comments by the Commission on RPA's Interim Report of 22 November 2006 and the Final Report of 22 February 2007.

The remaining sections of this Report are arranged as follows:

- Section 2 provides information on the **markets and use of DCM-based paint strippers** in the EU;

- Section 3 provides an overview of the **human health and environmental risks pertaining to DCM-based paint strippers**;
- Section 4 discusses **existing controls** on releases of and exposure to DCM;
- Section 5 outlines the existing information on possible **alternative stripping formulations and techniques** to DCM in various applications;
- Section 6 describes a range of **potential risk reduction measures** and outlines how they could apply to the uses of DCM-based paint strippers;
- Section 7 provides **the assessment of the potential risk reduction measures** against the standard decision criteria of their effectiveness, practicality, and monitorability;
- Section 8 presents an assessment of the **economic impact of potential restrictions**;
- Section 9 provides the **conclusions and recommendations for a risk reduction strategy**; and
- Section 10 presents the **references** used for this report.

The Report includes the following Annexes:

- Annex A is the **Project Specification**;
- Annex B presents the **markets information** by Member State for DCM and DCM-based paint strippers in European countries as well as market information on alternative paint stripping formulations in some European countries. Information on regulatory measures in specific Member States relevant to DCM is also included in this Annex;
- Annex C summarises the results of **relevant work undertaken in recent years** by consultants on behalf of the European Commission on DCM-based paint strippers and the associated risks;
- Annex D presents available data on **monitored exposure levels** during the use of DCM-based paint strippers and the relevance of vapour retardants in controlling exposure;
- Annex E presents the **available data on accidents and fatalities** associated with the use of DCM-based paint strippers and their alternatives;
- Annex F presents information on **volatile substance abuse**; and
- Annex G presents an overview of the **consultation activities** throughout this project and a list of consultees.

2. MARKETS FOR DCM AND DCM-BASED PAINT STRIPPERS

2.1 Manufacture and Supply of DCM in Europe

2.1.1 Manufacturing Process

DCM is mainly produced together with other chloromethanes e.g. methyl chloride and chloroform. The raw materials are methanol and chlorine and, to a lesser extent, methane and chlorine (Euro Chlor, 1999).

In the methanol hydrochlorination process, hydrogen chloride (HCl) reacts first with methanol to form methyl chloride which is then chlorinated (in a second step) to heavier chloromethanes through thermal, catalytic, or photolytic chlorination. Direct chlorination (either thermal or catalytic) of methane is also used for DCM production; however, the methanol hydrochlorination process, where no net hydrogen chloride is generated, is usually favoured, except when a nearby use of HCl is possible (e.g. vinyl chloride production) (Euro Chlor, 1999).

2.1.2 Manufacture of DCM in Europe

The interests of European chlorinated solvent producers and (industrial) consumers are represented by the European Chlorinated Solvent Association (ECSA) which is part of Euro Chlor (Euro Chlor represents 98% of the European chlor-alkali industry).

The members of ECSA that are known to manufacture DCM in Europe included in 2006:

- Arkema (France);
- Dow Europe (Switzerland - producing in Germany);
- Ercros (Spain);
- INEOS Chlor (United Kingdom);
- LII Europe (Germany); and
- Solvay (Belgium - producing in France and Italy (2 locations)).

All six manufacturers of DCM are large companies with more than 250 employees each and a turnover exceeding €50 million per year. This turnover does not relate to DCM alone.

ECSA has suggested that, following the expansion of the EU from 25 to 27 Member States on 1 January 2007 (with the accession of Bulgaria and Romania), there is one additional DCM manufacturer in the EU. This is a company called Chimcomplex located in Romania and is not a member of ECSA at present (ECSA, 2007). Input was requested from this company to this study, however, no information has been received to date.

Additionally, the Slovenian authorities (Slovenian National Chemicals Bureau, 2007a) have suggested that 185 tonnes of DCM are manufactured in Slovenia annually by two companies. The Bureau holds the register of companies that trade and manufacture dangerous chemicals and also holds data on quantities, compositions, uses and SDS. The estimate of 185 tonnes of DCM manufacture in the country was based on information from the register with no further detail available (Slovenian National Chemicals Bureau, 2007b).

2.1.3 Overview of Sales of DCM in Europe

According to data released by ECSA, recent DCM sales have followed the general trend for chlorinated solvents, i.e. a general decline which is expected to stabilise by late 2007 once the Solvents Emissions Directive 1999/13/EC is fully implemented. The Western European market for chlorinated solvents for the years 2001-2005 (based on ECSA sales data and Eurostat import figures, excluding intra-company transfers) is provided in Table 2.1. As can be seen from the table, DCM remains the most widely used of the chlorinated solvents.

Table 2.1: Sales of DCM and Other Chlorinated Solvents in EU-25 plus Norway, Switzerland and Turkey (tonnages for years 2001 – 2005)

Year	DCM	Trichloroethylene	Perchloroethylene	Total per year
2005	132,000	28,000	56,000	216,000
2004	133,000	33,000	54,000	220,000
2003	138,000	38,000	57,000	233,000
2002	142,000	52,000	60,000	254,000
2001	143,000	62,000	64,000	269,000
Average change	*-2.0%*	*-18.0%*	*-3.34%*	*-5.3%*

Source: ECSA Internet site (www.eurochlor.org/news/detail/index.asp?id=194&npage=1&category=25)
Note: The sales figures above are not comparable year on year. In 2004, ECSA started collecting sales data for the 10 new EU Member States and this is taken into account, but prior to 2004 only the 15 'older' Member States plus Norway, Switzerland and Turkey were included.

The statistics provided above for both DCM and other chlorinated solvents may be used in conjunction with data collected through consultation with the six individual manufacturers to estimate the level of extra-European exports of the six companies. The total tonnage for the manufacture of DCM in Europe for the years 2001-2005, as reported by these companies is presented in Table 2.2 (this table focuses on DCM only).

Table 2.2: DCM Sales in European and non-European Countries (tonnages for years 2001 – 2005)

Year	European sales tonnage from ECSA Internet site	Production tonnage from aggregated data of individual manufacturers	Difference (presumed exports to non-European customers)
2005	132,000	ca. 244,000	112,000
2004	133,000	ca. 257,000	124,000
2003	138,000	ca. 239,000	101,000
2002	142,000	ca. 223,000	81,000
2001	143,000	ca. 239,000	96,000

Source: Consultation with the six manufacturers of DCM - members of ECSA

The figure from exports calculated above for the year 2005 (112,000 tonnes) is very close to the aggregated tonnages of DCM exports as provided by the individual manufacturers during consultation (>3% difference) and may, therefore, be considered an accurate working figure. It is interesting to note that the sales to non European destinations appear to increase year by year while European sales follow the opposite direction.

For some manufacturers, the European market is far more important (as a percentage, not necessarily as a tonnage) than all non-European markets put together (personal communication with industry)). Notably, for two companies, the domestic markets in the countries they are located in are very important to their sales, while for three others the domestic markets account for a small percentage of total sales.

Of the six manufacturers-members of ECSA, one company has a dominant position in the European market with a production that accounts for over 25% of the total European production (not taking into account the production of companies that are note members of ECSA). Four of the companies account for 60 – 70% of the market and one company has a production of less than 10% of the total European production. Out of the six companies, two increased their DCM production considerably between 2001 and 2005, while the remaining four decreased their DCM production.

2.1.4 Markets for DCM in Europe

Table 2.3 summarises the information received from the key six manufacturers of DCM on the applications and markets to which they supply DCM in Europe.

Table 2.3: Breakdown of Sales of 'Virgin' DCM by Manufacturers to European Markets

Application category	Tonnage sold in the Europe	Number of suppliers selling in each sector
Pharmaceuticals	> 50,000	6
Paint stripping	ca. 13,000	6
Adhesives	5,000 – 10,000	6
Aerosols	1,000 – 5,000	6
Degreasing agent in the mechanical and electrical engineering industries	1,000 – 5,000	4 to 6
Extraction processes in the food industry	1,000 – 5,000	Less than 4
Coatings	< 1,000	Less than 4
Solvent or auxiliary agent in:	10,000 – 25,000	4 to 6
- foam blowing (e.g. polyurethane)	1,000 – 5,000	4 to 6
- polycarbonate production	1,000 – 5,000	Less than 4
- triacetate production	< 1,000	Less than 4
- degreasing	< 1,000	Less than 4
Other	5,000 – 10,000	4 to 6
Total	***ca. 110,000***	

Source: Consultation with the six key manufacturers of DCM – members of ECSA

The figures are given as ranges for commercial confidentiality reasons. Notably, there is a difference between the estimated sales aggregate presented by ECSA and the figures collected through consultation (even after adjusting for the likely levels of sales to Turkey which are normally included in the ECSA statistics).

In general, it should be borne in mind that there are considerable difficulties, which vary from company to company, in allocating sales and tonnages to specific applications. This may be because a manufacturer is not always sure of the nature of end users of his product when this is supplied through distributors or the data available to the company do not allow for a meaningful split. For example, the DCM that has been accounted for under "other" should ideally be considered under earlier categories; however, some companies could not provide a more detailed and specific breakdown of their sales.

The above figures should always be considered to be 'indicative'. As one manufacturer has pointed out, customer base and volumes sold to individual customers change as customers can source from other suppliers or from distributors supplied by the same manufacturer. Distributors do not always (accurately) inform the manufacturer where they sell the product (naturally, they may even not know as they mix different suppliers' product in their tanks) and are not obliged to do so. Also, the figures provided by the manufacturers depend on how different customers who have reported these data choose to allocate sales to application categories.

From Table 2.3, it is evident that the most important sectors for DCM sales – and the current trends - are (in descending order):

- ***pharmaceutical products***: one company shows an increase in sales over the last five years, three show a decrease (one of them a considerable decrease), and two companies have stable sales;

- ***paint stripping***: five companies indicate a decrease in sales over the last five years, while one indicates generally stable sales figures;

- ***solvent or auxiliary agent***; and

- ***adhesives***.

Table 2.4 outlines the size of the different European countries in terms of sales of DCM across all applications (not only paint strippers). This Table should be used for indicative purposes in identifying the key players by Member State.

Table 2.4: Relative Size of European Markets for DCM in 2005					
Percentage of Total Sales to European Countries (EU+EEA+CH)					
Highest (15.0-25.0%)	**High (10.0-14.9%)**	**Medium (5.0-9.9%)**	**Low (1.0-4.9%)**	**Very low (0.01-0.9%)**	**'Zero-sales' markets**
France Italy United Kingdom	Germany	Spain	Belgium Greece Hungary Ireland Netherlands Poland Switzerland	Austria Cyprus Czech Republic Denmark Estonia Finland Latvia Lithuania Norway Portugal Slovak Republic Slovenia Sweden	Iceland Liechtenstein Luxembourg Malta
Source: Consultation with the six key manufacturers of DCM – members of ECSA					

2.1.5 Structure of Supply Chains

The supply chains for the six key DCM manufacturers have both key similarities and differences. In summary, the following have been found through consultation with the six manufacturers:

- generally, the majority of the sales are made through traders/distributors (in some cases as much as 90% of sales), even where companies have local offices in different Member States. The number of distributors can be quite significant (up to 75) which, in some cases, greatly exceeds the number of direct customers;

- direct downstream users are essentially pharmaceutical companies and formulators;

- some of the formulators of paint strippers may formulate paint strippers and then sell them directly on to end-users or they may simply manufacture paint strippers on behalf of a client ('toll' manufacture); and

- the number of formulators of paint strippers which are directly supplied by DCM manufactures varies: one company sells DCM to only two such formulators, while another sells to 15-20 formulators.

2.2 Manufacture of DCM-based Paint Strippers in Europe

2.2.1 Sales of DCM for the Manufacture of Paint Strippers

Table 2.5 is based on the presentation made by CEFIC at the European Commission Forum on Paint Stripping Agents in Brussels on 14 November 2005 and incorporates more recent data that was made available to RPA by ECSA in early 2007 (ECSA, 2007).

Table 2.5: Sales of 'Virgin' DCM for Paint Strippers

Year	Tonnage of DCM sold
1995	ca. 20,000
2001	ca. 18,500
2002	ca. 18,000
2003	ca. 19,000
2004	ca. 15,000
2005	ca. 13,000

Source: CEFIC, 2005; ECSA, 2007
Note: Western Europe = EU-15 plus Norway, Switzerland and Turkey

Overall, the main destinations of paint-stripper related sales of 'virgin' DCM appear to be: France, Germany, Italy, Belgium, the Netherlands, Luxembourg (the last three are considered together), Spain, the United Kingdom and Ireland (the last two are considered together). This is generally the case for all years. In Table 2.6, the total sales for the year 2005 are broken down by country and a comparison of sales for the years 2002 and 2005 is provided.

Table 2.6: By Country Sales of 'Virgin' DCM for Paint Strippers in 2002 and 2005

Country	Sales in 2002	Sales in 2005	2002-2005 change (%)
UK/Ireland	4,267	3,228	-24%
France	4,779	2,530	-47%
Benelux	2,824	2,511	-11%
Germany	1,067	1,524	+42%
Spain	2,203	1,441	-36%
Italy	1,532	1,254	-18%
Rest of EU-15	1,056	716	-32%

Source: CEFIC, 2005; ECSA, 2007
Note: Rest of EU-15 = EU-15 plus Norway, Switzerland and Turkey

The general trend is towards a reduction in sales. This is evident for both total sales (around 13,000 tonnes down from 20,000 tonnes in 1995) and per country sales with most notable reductions in France, Spain, and UK/Ireland as well as in the rest of the EU-15. It is also of interest to note that contrary to the recent trends, the tonnage sold in

Germany has significantly increased by more than 40%. It is not clear why this has been the case and ECSA could not offer an explanation.

The information above complements information collected from four out of six key manufacturers regarding their sales of paint-stripper-related DCM to different European countries. These four companies account for around half of the total of ca. 13,000 tonnes of DCM sold in Europe. It should be noted that some of the respondents were not in a position to provide specific tonnages for some countries (presumably this occurs where their sales are not particularly significant or exact sales figures are incomplete).

The tonnage of ca. 13,000 needs to be considered alongside the quantity of DCM that is being recycled from the pharmaceuticals industry and which may end up into paint stripper manufacture. This is discussed in the following sub-Section.

It is not clear whether DCM is imported into Europe for the manufacture of paint strippers; only one manufacturer of DCM-based paint strippers has indicated that they use DCM imported from a non-European country.

2.2.2 Recycling of DCM and Relevance to DCM-based Paint Stripping

Use of DCM in the Pharmaceuticals Industry

DCM is the chlorinated solvent most widely used in the pharmaceutical industry. Specific product properties include a low boiling point, immiscibility with water, a resistance to emulsification and high specific gravity. These characteristics make DCM highly suitable to extract pharmaceutical compounds from water. In addition, DCM is completely miscible with various types of alcohol such as ethanol or isopropanol and methylcellulose, the coating for most pharmaceutical tablets. It is typically applied as a solvent for (Dow, 2007c):

- effective and optimised reaction conditions;
- extraction of certain pharmaceutical compounds; and
- re-crystallisation and tablet coatings.

The European Federation of Pharmaceutical Industries and Associations (EFPIA, 2006), notes that DCM is mostly used as a solvent in the synthesis of intermediates and Active Pharmaceutical Ingredients (APIs). It is also used in the coating process for gastro-resistant oral dosage forms and in the production of catheters and other medical devices. EFPIA is not aware of other uses of DCM in finished product manufacture and suggests that DCM is not added to finished products in Europe.

Information on Recycling of DCM into the Manufacture of Paint Strippers

For the purposes of this study, information was requested from EFPIA and its members and emails were sent to more than forty-five companies specialising in waste collection, disposal and recycling of spent solvents. In general, there was a limited response to these enquiries. EFPIA noted that some pharmaceutical companies using DCM had to be excluded from the scope of this study because they provided responses such as those listed below (EFPIA, 2006):

- "*DCM is used in a very limited amount below those mentioned in the questionnaire but there is not intention to re-sell or supply it*";

- "*DCM is recycled in the pharmaceutical company distillation facilities and the wasted DCM is burned in the pharmaceutical company facilities*"; or

- "*DCM is not reused, and disposed off by an approved supplier. The end treatment is a high temperature combustion where all emissions are treated in scrubbers*".

Three completed questionnaires were received from pharmaceuticals companies through EFPIA; four completed questionnaires were also received from companies recycling spent solvents. Additional questions were forwarded to these companies and some additional (but generally limited) information was received.

The total tonnage of spent DCM recycled within Europe by the respondents from the pharmaceuticals sector is around 1,500 tonnes (note that one of the companies that has responded is not located in Europe); however, only part of this is recycled and subsequently used in paint stripper manufacture. One company suggested that only around 10% of its spent DCM may be recycled by companies which may then sell it to paint stripper formulators.

On the other hand, the combined tonnage of recyclable spent DCM collected by the four recycling companies is around 1,400 tonnes for the year 2005.

Overview of Consultation

Table 2.7 overleaf summarises the available information on supply chains. A number of key points can be made here on the basis of the collected information:

- very few manufacturers of DCM-based paint strippers positively indicated that they use recycled DCM in their manufacture. On one particular occasion, the recycling company is also a manufacturer of DCM-based paint strippers and utilises a large portion of its own recycled material in the manufacture of DCM-based paint strippers;

- the use of recycled DCM may not always be desirable. For instance, a company that manufacturers a significant tonnage of DCM-based paint strippers has advised that they have stopped using reclaimed material after they started to get pin holes in the pipework (made of stainless steel). The company concluded that this was due the production of chloride ions from the breakdown of DCM. This in turn came from a lack of inhibitor in the reclaimed grade (note the discussion in Section 1.2 on the use of amylene in DCM). The company considered two options: either to replace the pipe run or to opt for 'virgin' material (which would also improve product quality). The company recognises that there was no 100% certainty that the use of reclaimed

DCM was to blame for the pin holes, however they were satisfied that their assertion had a sound basis. The company could not comment on whether such phenomena might affect its customers, however, the company assumes that if it takes a long while for such corrosion phenomena to occur, their customers may attribute the phenomenon to the old age of the equipment rather than the use of reclaimed DCM and simply replace their tanks. The company did not want to consider the addition of an inhibitor to the reclaimed DCM since the presence of "corrosive contaminants" could vary between batches of reclaimed material;

Table 2.7: Supply Chain Actors in the Recycling of DCM in Europe

Companies	Number of suppliers	Number of clients/recyclers
Pharmaceuticals companies		
Company A	Several suppliers of 'virgin' DCM in different locations	4 companies located in 3 European countries
Company B	No information	1 company located in the country where DCM is 'spent'
Waste recycling companies		
Company W	***Year 2006***: 5 suppliers of spent DCM (3 intermediaries and 2 producers (organic synthesis companies)) (60% from the 2 producers) ***Year 2005***: 9 suppliers of spent DCM* (50% from a single company)	3 users (the 3 intermediaries who supplied the spent DCM) in the home country of the recycler 50% of recycled DCM was probably sold outside the EU
Company X	7 suppliers of spent DCM	4 users of recycled DCM
Company Y	No information	Unknown number of clients in 2 European countries
Company Z	9 suppliers of spent DCM	7 users of recycled DCM

Source: Consultation
** in reality, 3 different intermediaries supply spent DCM on behalf of 8 companies, therefore, a total of 14 producers of spent DCM are linked to this recycling company*

- the fact that spent DCM is to be sent for recycling does not mean that the entire tonnage will be reclaimed or in fact it will be passed on to a paint stripper manufacturer. For example, a recycling company suggested that 10% of the material collected was lost in the reclaim process. Another recycling company suggests that more than 26% of the collected DCM is lost in the reclaim process the process. A third recycling company obtained only 55% of the original quantity of spent DCM; notably this company recycles significant quantities of spent DCM. On the other hand, a pharmaceutical company suggests that only around 10% of his recyclable DCM ends up at companies that sell the distillate for technical applications (rather than HCl recovery by incineration); another pharmaceutical company recycles 40% of its spent DCM towards the manufacture of DCM-based paint strippers and believes that such a recycling rate is representative of this sector. Finally, even the company that both recycles and manufactures DCM-based paint strippers does not use the entire reclaimed tonnage in the manufacture of paint strippers. For this company, just 67% of the originally collected DCM is diverted to the manufacture of paint strippers;

- the reclaimed material is often sold to distributors/intermediaries rather than individual users; therefore, it is difficult for companies such as pharmaceuticals companies and waste disposal/recycling companies to know what exactly is the fate of the reclaimed DCM; and

- the quality of collected DCM is variable and it is safe to believe that while the pharmaceuticals industry probably produces high quality/purity spent DCM, other industry sectors may not. Other sources of spent DCM may include:

  - the shoe industry;
  - the polyurethane moulding industry;
  - the polyester moulding industry;
  - the metal cleaning industry; and
  - the photographic materials (film) industry.

  This information was collected during consultation; the relative importance of the above sectors to the recycling of DCM is currently unknown.

Estimated Levels of DCM Recycling in Europe

Due to the limited number of responses from industry, it cannot be calculated at present, with any certainty, the tonnage of DCM which is recycled into the manufacture of paint strippers in Europe. However, some information from consultation and from past reports on DCM in paint strippers (and other applications) may be useful in providing an estimate.

As CEFIC (2005) notes, the TNO report (1999) has assumed that the total use of DCM in paint strippers in 1995 in the EU-15 was about 30,000 tonnes; this included:

- 20,000 tonnes of 'virgin' material; and
- 10,000 tonnes of recycled product.

On the other hand, the ETVAREAD report (2004) used data from CEFIC and assumed that, in 2002, the use of DCM in paint stripper manufacture in the European Union involved 26,000-30,000 tonnes of DCM and more specifically:

- 17,860 tonnes of 'virgin' DCM; and
- 8-12,000 tonnes of recycled DCM.

In estimating the tonnage of DCM recycled into paint stripping manufacture, the following assumptions (and tentative calculations) have been made:

- ***imports and exports of DCM***: it is possible that EU pharmaceuticals companies import 'virgin' DCM from non-EU manufacturers. Additionally, non-EU pharmaceutical companies may pass on their spent DCM to EU recyclers who may then sell the distillate to EU manufacturers of DCM-based paint strippers. On the basis of the lack of any information on these trade flows, it is assumed that these potential flows of DCM mutually cancel each other out and as such, have not been taken them into account in the estimates;

- ***number of pharmaceutical companies recycling DCM***: as described by EFPIA (see above), not all pharmaceuticals companies may recycle the DCM they use. No information is currently available on what proportion of these companies recycle DCM; therefore, it is assumed that 50% of all DCM sold to the EU pharmaceuticals industry will be subject to recycling;

- ***recycling rate for pharmaceuticals companies***: the responding pharmaceuticals companies (who purchase DCM from European manufacturers) indicate that for the companies who recycle their spent DCM, the recycling rate depends very much on the processes which a pharmaceuticals company uses DCM for. One respondent with a recycling rate of 10% of his consumption suggested that in previous years they had recycling rates up to 30-35%. A second respondent believed that his recycling rate of 40% was representative of other recycling companies. Therefore, a recycling rate of up to 50% is not unrealistic. In total, a recycling rate of 10-50% is assumed;

- ***output rate of recycling process***: as expected, the tonnage of the distillate after recycling is smaller than the original tonnage of spent DCM. Two companies that provided information suggest losses of 26% and 45%. Assuming that spent DCM from pharmaceutical companies will contain a relatively limited percentage of contaminants and that the pharmaceuticals industry is the main source of spent DCM, it is assumed that only 25% of DCM is lost in the recycling process; and

- ***percentage of distillate used in the manufacture of paint strippers***: the information available suggests that the reclaimed DCM does not necessarily end up in the manufacture of DCM-based paint strippers. The percentage that does may vary widely (see information above suggesting a percentage of 10% or 67% or even 100%). As a conservative approach, it is assumed that between 67% and 100% will indeed be used by manufacturers of paint strippers (however, it is clear that manufacturers prefer 'virgin' DCM since the price differential between 'virgin' and reclaimed DCM is small).

In all, starting from total sales of 'virgin' DCM to the pharmaceuticals sector of more than 50,000 per year and using the assumptions above, the tonnage of reclaimed DCM that is used in the manufacture of paint strippers is calculated to be between 1,500 and 11,000 tonnes DCM per year. The upper limit is in agreement with estimates in the TNO and ETVAREAD reports and will be taken forward in our analysis later in this report.

In conclusion, it is assumed that the total tonnage of DCM sold for use in paint stripper manufacture in Europe in 2005 was 24,000 tonnes (13,000 tonnes of 'virgin' DCM + 11,000 tonnes recycled/reclaimed DCM). As discussed in Section 2.3.4 below, it is believed that the average DCM-based paint stripper has a concentration of DCM in the range of 60-90%; therefore, the tonnage of DCM-based paint strippers manufactured in Europe in 2005 is estimated to have been 26,700-40,000 tonnes.

It should be noted that the available evidence points to a gradual reduction of waste DCM produced in the pharmaceuticals industry as sites implement solvent management and reduction plans (see Box 2.1). Moreover, data from recycling companies also suggests a decline in the tonnages of recycled DCM.

Box 2.1: DCM and Waste Minimisation in the Pharmaceutical Industry

Information from a Pharmaceuticals Company (from consultation)

"<Our company> *uses best available techniques to minimise environmental releases of solvents including DCM. Chemical Development teams work on processes to improve their efficiency and to minimise the use of solvents including DCM.* <Our company> *has also developed a Solvent Selection Guide which encourages/helps chemists to select solvents, which are less harmful to human health and the environment. I understand that most other pharmaceuticals companies are making similar efforts… Year on year, the amount of waste DCM has fallen as sites implement solvent management and reduction plans."*

Case Study on the Recovery of DCM from Pharmaceuticals Processes

Title: Recovery of DCM from Pharmaceutical Reaction Distillation Reduces Waste
Case Study Source: US Natural Resources Defense Council (ChemAlliance, 2006)
Company: Dow Chemical Company/Midland, Michigan/USA (Pharmaceutical and Medicine Manufacturing)

Dow produces pharmaceutical products under contract for another company. DCM is used as a chemical processing aid to keep raw materials and intermediates in solution as they react to form the final product. DCM is first distilled during the product reaction and then again during the quench reaction. The DCM is then burned in the on-site incinerators.

Recovering the DCM from the product reaction distillation step was pursued. Of particular concern was the potential build-up of impurities in the system and the impact of these impurities, if present, on the product. Dow conducted pilot trials to determine any impacts on product quality and to develop technical data for the design of the final system. To conduct the trials, Dow installed temporary piping systems to recycle the DCM to produce a sufficient number of batches. The product was tested in Dow's quality assurance labs to ensure no impurities were present.

The estimated reduction in DCM sent to incineration is 273,000 lb (ca.124 tonnes). Initially, Dow recycled approximately 50% of the DCM for quality assurance testing. Subsequently the number of times solvent is recycled before incineration has slowly been extended. Test results show no impact on product quality to date, and Dow's goal is to recycle about 95% of all of the DCM from the product reaction distillation step. This will result in in-process recycling of 75% of the total DCM waste from the process.

Economics: The construction of a permanent recovery system is estimated to cost approximately $140,000 and save approximately $450,000 per year in raw material costs and waste treatment costs (these are equivalent to around €105,000 and €335,000 respectively – 2007 exchange rate of $1=€0.75)

2.2.3 Manufacture of DCM-based Paint Strippers in Europe

During the course of the study, a significant number of companies were contacted that manufacture DCM-based paint strippers. Moreover, some companies were also contacted indirectly via their national and European trade associations as well as their national authorities. In summary:

- information (in the form of completed questionnaires) has been received from twenty companies located in seven different countries (seven of the companies are located in the UK);
- thirteen companies (or 65% of the respondents) are SMEs while seven are large companies (based on workforce levels); and
- nine (confirmed) companies (six SMEs and three large companies) also manufacture alternative paint stripping formulations.

Table 2.8 presents the aggregated tonnages for all respondents; information on tonnages was not received from three companies. The total tonnage for 2005 represents approximately 10% of the total European manufacture as estimated in Section 2.2.2.

Table 2.8: Overview of European Production of DCM-based Paint Strippers from Respondents to the RPA Questionnaire

Year	Tonnage	Companies reporting tonnages
2005	4,780	17
2004	4,765	16
2003	4,605	12
2002	4,055	12
2001	3,750	10

Source: Consultation data – responses from a total of 20 companies

The vast majority of companies manufacturing paint strippers indicate that their products contain vapour retardants. Three companies do not use vapour retardants and were further requested to provide further details on this – one declined to provide information (incidentally, its products are manufactured by a third party) while no information has been received from the second company. The third company supplies (but does not manufacture) DCM-based paint strippers for professional uses (paint removal on metallic surfaces before repainting). It should be noted that the products of the first of the two companies only find industrial uses in the aerospace sector while the products of the other appear to be equally split between industrial use in the metals industry and industrial use in the vehicle repair industry. Two other companies supply products both with and without vapour retardants for industrial uses only. For the purposes of this analysis, and as discussed later in this report, vapour retardants will be considered to be paraffin waxes. Other materials used to control the evaporation of DCM in paint stripping applications are discussed in Annex D to this report.

On the basis of the information from the companies that provided tonnage data for the year 2005[8], the most important markets (in terms of size) appear to be Germany, Ireland

[8] Note that the sum of tonnages at the Member State level is around 1,250 tonnes; not all respondents who provided production data have also provided a breakdown of their sales per country, presumably, on grounds of commercial confidentiality.

and the United Kingdom. This appears not to diverge from sales data presented earlier in this Section, however, it has to be noted that in this data set, the combined sales to Germany and the United Kingdom account for 86% of European sales; this demonstrates that the majority of information collected relates to these two Member States.

2.3 Use of DCM-based Paint Strippers in Europe

2.3.1 Overview

DCM ensures fast stripping due to the small size of the molecule, which allows it to penetrate across micro-pores of the coating and release the layer of adhesion (chemical liaison) between the coating and the substrate. The blistered coating can then be efficiently removed.

DCM-based paint strippers are used by consumers for DIY activities, professional painters/decorators and maintenance tradesmen, and in an industrial environment. For the purposes of this study, these three main use categories are defined as follows:

- ***industrial use***: for instance, when DCM-base paint stripper is used in an stationary technical unit (for instance, metal stripping, furniture stripping, automotive stripping, aircraft stripping, etc.);

- ***professional use***: for instance, when DCM-based paint stripper is being used for the removal of paint from exterior and interior walls of buildings, removal of graffiti, removal of paint from doors and window frames by a tradesman (not a consumer) – this use takes place either outdoors (possibly on a scaffold) or at or around the premises of a client; and

- ***consumer use***: for instance, when DCM-based paint stripper is used for DIY activities both indoors and outdoors.

Paint stripper is mainly used to remove an old, bad coat (blistered, cracked, etc.) of paint to which fresh paint may not be applied. The field of application of stripping agents by the consumer and occupational users is mainly focused on the removal of bad and blistered paintwork on wood, both indoors and outdoors. It is also applied for restoring old furniture and removing glue residue from staircases and floors. With particular regard to industrial uses of these formulations, paint strippers are used for surfaces that need to be stripped completely, for example, during the maintenance of aeroplanes, refinishing activities for automotive parts, furniture, metal objects, etc. Industrial paint stripping takes place either by immersion in a DCM-based bath, or by spraying the surface with paint stripper (UK HSE, 1998) although application by brush (similar to that employed by consumers) cannot be excluded, if a small job needs to be undertaken.

On the basis of information collected through consultation with manufacturers of DCM-based paint strippers, the uses/applications of DCM-based paint strippers can be summarised as follows:

- **Industrial uses (using a dip tank or other application method):**
  - removal of air drying paints in wood and metal objects;
  - paint removal in furniture strip-shops (including stripping and restoration of antique furniture);
  - removal of coatings from machine & automotive parts (this may include the cleaning of walls in spray booths or cleaning of floors around the spray booth);
  - stripping paint from aircraft and (occasionally) from rail vehicles;
- **Professional uses:**
  - in situ paint removal from woodwork[9], brickwork, plasterwork, stonework, concrete, cast iron;
  - in situ removal of coatings from buildings, facades, timber & steel structures (including conservation work and historical building maintenance);
  - stripping walls and floors, window frames, doors, skirting boards, etc.; and
  - graffiti removal (including removal of graffiti on behalf of local authorities – usually from wall surfaces - and removal of graffiti from vehicles).
- **Consumer (DIY) uses:**
  - removal of paint from woodwork, brickwork, plasterwork, stonework, concrete, cast iron at home (indoors and outdoors, for example, cast iron garden furniture); and
  - removal of paint domestic dwellings on wood and metal articles such as wooden doors, skirting rails/boards, window frames, hand rails, staircases, etc., especially for removal of varnishes, lacquers, nitro lacquers, polyurethane lacquers and plastic coatings.

9 A particular type of coating removal has been indicated by some UK consultees and has been associated to "French polishing". French polishing is a method of applying shellac by hand, although in recent times companies have opted for solvent-based spray lacquers which are much more hard-wearing and serviceable. DCM-based paint strippers may be used to carefully remove such coating from antiques (fine veneers). This coating may be 0.5-1 mm thick. Sanding it once may work, but more than once (for maintenance purposes) will destroy the article surface. If there is a moulded edge then sanding may remove the moulding, i.e. it has to be stripped.

It is of note that DCM-based products find applications that may have similarities to paint stripping but are not exactly this and, therefore, fall outside the scope of this study. These include cleaning, degreasing and decarbonising processes in the metal treatment, electronics and automotive industries and elsewhere.

This study will generally focus on the above three use categories, rather than the specific sub-categories, in analysing the impacts of any restrictions. The following paragraphs present the detailed information received on the use of DCM-based paint strippers in some industrial sectors.

Use of DCM-based Paint Strippers in the Automotive and Rail Industry

Information has been received from a company running eight branches across the UK that use DCM-based products for paint stripping and carbonised oil removal. For paint stripping the product is used in a vat containing between 200-400 litres with a water vapour barrier. This paint stripping activity is mainly applicable to aluminium casings from rail applications. The product is also occasionally used as a brush applied paint stripper on radiator housings (mainly commercial vehicle radiators).

Use as a carbonised oil remover is normally achieved by either dipping the item to be cleaned in a vat containing DCM or by pumping the DCM formulation through the unit and then flushing with steam cleaners.

The company also noted that it sells DCM-based paint stripper in 500ml tins to the UK automotive market. The company is of the opinion that the use of this product is occasional in most vehicle repair applications, due to falling incidence of original panel repairs.

Use of DCM-based Paint Strippers in the Shipbuilding Industry

Information has been received from the International Council of Marine Industry Associations (2006) and the Community of European Shipyards' Associations (2006). It has been indicated that the professionals of the yacht industry are not using paint strippers. Chemical paint stripping is a considerably time consuming process for companies, and, therefore, not economical and hence it is not used. They mostly use dry and wet blasting (for the larger steel and or aluminium boats/yachts) and/or high water pressure cleaning at a special environmentally safe prepared area within their facilities. Only the retail sector of yacht industry is selling paint strippers to the consumers, the owners/users of the boats and yachts. The tonnages involved are currently unspecified. The Community of European Shipyards' Associations has also confirmed that the situation for its members is similar to the one described by the International Council of Marine Industry Associations.

Use of DCM-based Paint Strippers in the Aerospace Industry

A formulator has estimated the size of the paint removal sector for the aerospace industry in Europe at around £4million per annum. The key players in the sector include:

Paint stripper formulators	There are six key formulators in Europe, two in the UK, one in Germany, one in France and two in the USA. Two of them have been said to supply DCM-based paint strippers in Europe, while a third may do so in Russia. Two of the three companies have a large share of the market as they are selling all types of paint strippers
Airlines	Lufthansa, BA, KLM, Iberia, SAS, TAP, Air France, Alitalia
Paint removal contractors	Two contractors in the UK (the largest in Europe), five contractors in the Netherlands, several small contractors in Eastern Europe and Scandinavia
Main paint removal locations	Germany, UK, the Netherlands, Spain, France, Portugal, Italy, Ireland, Switzerland, Czech Republic, Romania
Sizes of containers and quantity used for a typical job	Most aviation paint stripping products are sold in 200 litre drums or 1,000 litre totes. A Boeing 747 may require 3-4,000 litres to strip

Information received from formulators suggests that DCM-based paint strippers currently find limited use; the main users have been suggested to be one large contractor in the UK, companies in Spain, possibly Portugal and many military locations Europe-wide. Belgium, the Netherlands, Scandinavia, Ireland, UK (with the exception of the contractor referred to above) and Germany generally do not use DCM-based paint strippers. In the German aerospace market more specifically, an approximate 90% decrease in DCM usage occurred at about 1990.

It has been estimated that DCM-based paint strippers represent around 25% of the paint stripper market in Europe; 65% of the market is taken by benzyl alcohol/formic acid formulations; the remainder is taken by alkaline strippers, peroxide strippers, etc. In the recent seven or so years the use of hydrogen peroxide/benzyl alcohol products has increased significantly.

It has been indicated that some formulators are in discussions with (military) aerospace manufacturers to develop systems that replace DCM with alternatives.

<u>Specifications and Standards for Aerospace Paint Stripping</u>

Depending on the type of material being stripped, there are a series of testing that needs to be repeated which are very costly and time consuming. A formulator has suggested that customers prefer to use products that have had approval from other airlines in house testing; it can be difficult to get these products in for testing. Many users of paint strippers in this industry have approval manuals which they do not update very often (years) and they will only use products listed on these manuals. The military have their own additional specifications that the product must be tested to and conform to.

It may be very time consuming to get a revision of standards and approvals for DCM-free paint strippers, according to a formulator. For example, the formulator notes that companies in the UK had waited for a decade for the latest RAF specifications.

2.3.2 Information on Current Trends in the Use of DCM-based Paint Strippers in the EU

Table 2.9 summarises the responses received in the course of this study. Although only limited information was received from individual companies on current trends, the information on the table appears to suggest a stable to downward trend, especially for industrial and professional uses of DCM-based paint strippers. It should be stressed that several companies did not fully answer the questions regarding the trends in their sales over the last five years.

Table 2.9: Overview of Sales Trends for Some EU DCM-based Paint Stripper Manufacturers

Country	SME?	Manufactures alternatives?	Range of tonnage of DCM-based paint strippers sold in 2005	Sales break-down (%)	Sales trends in the last 5 years		
					Industrial uses	Profess-ional uses	Consumer uses
DE	N	Y	20-500	IND: 5 PROF: 95 CON: 0	Stable	Decrease	-
DE	Y	Y	50-100	IND: 100 PROF: 0 CON: 0	?	-	-
EL	N	?	10-50	IND: 0 PROF: 0 CON: 100	-	-	?
EL	Y	N	10-50	IND: 0 PROF: 100 CON: 0	-	Decrease	-
IE	Y	Y	50-100	IND: 5 PROF: 15 CON: 80	Stable	Stable	Decrease slightly
NL	Y	N	50-100	IND: 100 * PROF: 0 CON: 0	Increase	-	-
NL	N	Y	10-50	IND: 100 PROF: 0 CON: 0	?	-	-
PT	Y	?	<10	IND: 100 PROF: 0 CON: 0	?	-	-
PT	N	N	10-50	IND: 5 PROF: 75 CON: 20	Decrease	Decrease	Slight increase
PT	Y	N	<10	IND: 0 PROF: 50 CON: 50	-	Decrease	Decrease

Table 2.9: Overview of Sales Trends for Some EU DCM-based Paint Stripper Manufacturers

Country	SME?	Manufactures alternatives?	Range of tonnage of DCM-based paint strippers sold in 2005	Sales break-down (%)	Sales trends in the last 5 years		
					Industrial uses	Profess-ional uses	Consumer uses
PT	Y	N	?	IND: ? PROF: ? CON: ?	?	?	?
PT	N	N	10-50	IND: ? PROF: ? CON: ?	?	?	?
ES	Y	Y	10-50	IND: 50 PROF: 50 CON: 0	Stable	Stable	-
UK	N	N	200-500	IND: 0 PROF: ? CON: ?	-	?	?
UK	Y	Y	?	IND: <3 PROF: <40 CON: >50	Decrease	Stable	Increase
UK	Y	Y	100-200	IND: 100 PROF: 0 CON: 0	Stable	-	-
UK	Y	Y	100-200	IND: 0 PROF: 60 CON: 40	-	Increase	Increase
UK	Y	Y	50-100	IND: 100 PROF: 0 CON: 0	Decrease	-	-
UK	N	Y	>500	IND: 0 PROF: 50 CON: 50	-	Stable	Stable
UK	Y	Y	?	IND: 20 PROF: 20 CON: 20	Decrease	Increase	Stable
				Number of responses	Increase: 1 Stable: 4 Decrease: 4	Increase: 2 Stable: 4 Decrease: 4	Increase: 3 Stable: 2 Decrease: 2

Source: Consultation
** The company sells only to furniture workshops which for the purposes of this report should be classified as an "industrial use" rather than "professional" as indicated in the company's response*
Also note that some companies may manufacture alternatives but the size of the alternatives business could be smaller or larger than the DCM-based side of their business.

2.3.3 Use Applications of DCM-based Paint Strippers by Member State

Table 2.10 below sets out the available information for a number of European countries on the split of the domestic (national) consumption of DCM-based paint strippers among the three broad categories of industrial, professional and consumer applications.

From the Table, it can be seen that the use of DCM-based paint strippers in countries such as Cyprus, the Czech Republic, Greece, Norway, the Slovak Republic, Slovenia and Switzerland mostly takes place in an industrial environment. Strong presence of consumer uses (occasionally dominance) can be found in: Latvia, Lithuania, Ireland, Estonia, and Norway. No data are available for key markets such as Belgium, France, Germany, Italy, the Netherlands, Poland, Spain and the United Kingdom. However, for the United Kingdom and Ireland, it is known that there is a considerable DIY market for DCM-based paint strippers.

Table 2.10: Breakdown of DCM-based Paint Stripper Applications per Country

Country	**Application categories**			**Source (and notes)**
	Industrial	**Professional**	**Consumer**	
Austria	Restricted			
Belgium	No available data			
Cyprus	100%			Cypriot Department of Labour Inspection, 2006a 100% for industrial uses is assumed as the two manufacturers of DCM-based paint strippers have been allocated by the Competent Authority under this category
Czech Republic	93% (of workers exposed)	7% (of workers exposed)		Czech National Institute of Public Health, 2006 Assumption based on data from the Institute: "*the total number of workers using DCM in workplace from National Exposure Data Base is 274 (117 women) in 40 companies, incl. 20 paint strippers*"
Denmark	0% (100%)		0% (not permitted)	Danish Working Environment Authority, 2006a The Authority notes "*in case of an application (for use of the paint strippers), an approval will probably not be given due to the existents of less hazardous alternatives*"
Estonia		65%	35%	Estonian Health Protection Inspectorate, 2006a
Finland	No data available to allow a split			Finnish National Product Control Agency for Welfare and Health, 2006
France	No available data			
Germany	No available data			
Greece	50% Tonnage 5% of exposed users	40% Tonnage 90% of exposed users	10% Tonnage 5% of exposed users	Greek General Chemical State Laboratory, 2006a
Hungary	Unknown split; reported not to be generally used			Hungarian National Institute of Chemical Safety, 2006 (after consultation with the Association of Hungarian Paint Manufacturers)
Iceland	No distinction can be made			Icelandic Environment and Food Agency, 2006a

Table 2.10: Breakdown of DCM-based Paint Stripper Applications per Country				
Country	**Application categories**			**Source (and notes)**
	Industrial	**Professional**	**Consumer**	
Ireland	5%	15%	80%	Irish Health and Safety Authority, 2006a Based on tonnage data
Italy	No available data			
Latvia	10%		90%	Latvian Environment, Geology and Meteorology Agency, 2006 Tonnage assumptions
Liechtenstein	No available data			
Lithuania	15%		85%	Lithuanian Environmental Protection Agency, 2006a Tonnage assumptions
Luxembourg	No available data			
Malta	"Extensively used" 4% of exposed users	"Relatively common use" 13% of exposed users	Relatively common use" 83% of exposed users	Malta Standards Authority, 2006
Netherlands	No available data (voluntary action now in place for graffiti removal)			RIVM, 2006a
Norway	72%		28%	Norwegian Pollution Control Authority, 2006 Tonnage calculations
Poland	No available data			
Portugal	Unclear; up to four respondents supply companies involved in industrial uses, up to six respondents supply companies involved in professional uses, up to four respondents supply consumers. For those companies that have provided specific breakdown, consumer uses are either low or nil			Consultation with Portuguese manufacturers and suppliers of DCM-based paint strippers
Slovak Republic	100%			Centre for Chemical Substances and Preparations of the Slovak Republic, 2006 Tonnage data
Slovenia	95%	0.01%	4.99%	Slovenian National Chemicals Bureau, 2007a
Spain	No available data			
Sweden	Restricted			
Switzerland	93% of commercial products on the market		7%; (2 products may not no longer be on the market)	Swiss Federal Office of Public Health, 2006a Not possible to separate industrial from professional; no tonnage data available
UK	No available data			
Source: Consultation with Competent Authorities				

It is evident that there is a lack of data for key markets in Europe. Moreover, for a number of countries, the available data present the split between numbers of users exposed (Czech Republic, Malta) or numbers of products available on the domestic market (Switzerland).

2.3.4 Concentration of DCM in DCM-based Paint Strippers

Consultation findings from 16 companies that manufacture DCM-based paint strippers indicate that:

- six companies market products with a DCM concentration higher than 80% with a maximum concentration of 95%;
- fourteen companies market products with a DCM concentration higher than 60%; and
- only two companies market products with a DCM concentration as low as 40% or 50%.

In all, it can be assumed that the majority of preparations available on the European market have a concentration of DCM between **60% and 90%**. TNO (1999) has assumed DCM-based paint strippers contain 50-80% DCM while the ETVAREAD report uses a narrower range of 75-80%. TNO (1999) also notes that there are also DCM formulations on the market with a DCM content of around 10-15% containing other solvents like methanol as a replacement mainly for cost-effective reasons. This is compatible with information from a number of sources:

- a manufacturer of DCM-based paint strippers for industrial applications noted "*the* (DCM) *percentage ranges from one up to nearly eighty percent. Sometimes you need DCM as a 'starter'; sometimes DCM is the main (active ingredient) of the mixture*";

- the French authorities have identified in their National Database of Products and Preparations (BNPC) six paint stripping products available on the French market that contain less than 10% DCM and a further forty-one preparations that contain between 10 and 50% DCM (see Table B8.2 in Annex B to the report). The total number of DCM-based paint stripping formulations is 401; and

- a completed questionnaire submitted by the Slovenian Competent Authority suggests that the concentration of DCM in vapour-retarded formulations may range between 10-25% (Slovenian National Chemicals Bureau, 2007a).

2.3.5 Key Components of DCM-based Paint Strippers

Overview

The French Ministry of Labour (2006a) has provided a detailed description of the composition of DCM-based paint strippers (what the Ministry calls "ink, paint and varnish strippers"). Based on 60 formulations available on the French market which were checked by the Ministry, half of the stripping products were found to be produced using DCM. Products based on DCM also contained (French Ministry of Labour, 2006a[10]):

- ***other solvents***: DCM alone does not have a sufficient capacity to strip a surface. The synergy with at least one other solvent (very often, methanol) gives the formulation more power to strip; methanol has also been suggested as being used for gelling the thickener(s);

- ***co-solvents and thinners***: these are added to improve the efficiency of stripping or to diminish the cost of the product without compromising the product's performance;

- ***vapour retardants***: the most effective strippers are solvents with a strong vapour pressure that have the tendency to evaporate before the stripper has time to penetrate the (final) coat. Hence, the addition of paraffin waxes with low melting point (46-67ºC) creates a layer on the surface as soon as the solvent starts to evaporate (and thus, when the mixture cools down), and forms a barrier against further evaporation. Certain esters are also added to reinforce the efficiency of this coating barrier; these include: phosphoric esters, esters of dodecyl benzenesulphonic acid, esters of alkylarylsulphonic acids, esters of phosphoric acid and 2-ethylhexanol.

  Strippers must be used within the optimal temperature range of 13 to 18ºC. When temperatures are lower than 13ºC, the wax solidifies completely and the product is not as effective. If the temperature is above 18ºC, the formulation of the wax layer is impeded which makes the DCM evaporate too quickly, before the reaction can take place with the coat of paint. Co-solvents such as pure turpentine oil & white spirit are used to pre-dissolve the paraffin wax prior to addition to the DCM, while solvents such as industrial methylated spirits control the solubility of wax in the DCM solution;

- ***surfactants***: surfactants are added so products can be rinsed with water; they are also useful in allowing the paint stripper to be easily washed off from brushes etc.;

- ***anionic surfactants***: formulations containing DCM may also contain alkylaryl sulphonates[11], or fatty acid salts, or non-ionic surfactants for special applications;

- ***activators***: activators increase the stripping efficiency by reducing the resistance of the polymeric coating. For example, acids are required in formulations that remove polyurethane resin and epoxy or strong bases for stripping enamel and latex;

- ***thickeners***: these are natural or synthetic polymers which disperse or swell when added to a protic solvent or when the pH is adjusted. They are chosen for not being

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10 Some additional detail from consultation with industry has also been used in drawing up the bulletpoints on this page.

11 According to the French Ministry, this applies to all identified DCM-based products in their database.

hydrolysed by acid or by the activator base in the formulation. They increase the viscosity of the stripping product, which is particularly useful for vertical surfaces[12];

- ***corrosion inhibitors***: phosphates (e.g. triethyl ammonium phosphates), propylene or butylene oxides are at times included in the formulations to assure the stability of the stripper in its packaging or to protect the substrate in case acid formulations were used on non-ferrous metals; and

- ***water and colorants***: a small percentage of water may also be present in DCM-based formulations.

It should be noted that the above components may be found in products available on the French market (as said, a selection of 60 of them, not all products). However, the list above is used to provide a general idea of what types of components might be found in formulations elsewhere in the EU. Note that in Annex B, the information for France provides an indication of the percentage of formulations that may contain the above ingredients.

It has been suggested that DCM-based formulations are essentially developed by a 'trial-and-error-system', since DCM on its own is 'not of much use': "*with some additional components you will get* (desirable) *products; say, DCM is not able to dissolve a specific* (paint). *With one alcohol and some other components, it will dissolve this lacquer entirely, with another alcohol the lacquer is split into tiny particles which you can filtrate out of the solvent mixture. But which alcohol is doing what and why we do not know* (before testing)", a manufacturer of DCM-based paint strippers has suggested. A typical example is the use of phenol and methanol (as is the use of ammonia, caustic substance, etc): phenol helps to remove tenacious paint films in conjunction with DCM; "*on some paint schemes methanol helps with phenol, for others it slows the stripping*" suggested another manufacturer of DCM-based paint strippers.

Concentration of Components

Table 2.11 presents an overview of the components of DCM-based paint strippers (other than DCM) which have been identified thus far. The sources of this information include the submissions by Competent Authorities in different countries, completed questionnaires submitted by industry and a number of Safety Data Sheets of relevant products. Where a substance was included in more than one formulation (for instance, methanol is included in a considerable proportion of DCM-based paint strippers), the minimum and maximum possible concentration have been identified across all relevant formulations and these upper and lower limits are presented in the table below. The components are presented in decreasing concentration order although there are a number of components without an indicative concentration range and these are presented towards the end of the table.

12 A DCM-paint stripper manufacturer has suggested that thickeners also help in reducing losses (and exposure) in the case of a spillage.

This list should not be considered as a comprehensive one as there may be several products available on European markets that may contain other substances which have not been identified during the preparation of this report.

Table 2.11: Example Components of DCM-based Paint Strippers

Components	CAS Number	Concentration in formulations
Mineral oil	8042-47-5	Up to 30
Ethanol	64-17-5	10-<30
Water	7732-18-5	Up to 20
Methanol	67-56-1	2-20
Phenol	108-95-2	10-20
Propan-2-ol	67-63-0	<2.5-20
Formic, sulphonic, acetic or hydrofluoric acid	64-18-6 27176-87-0 64-19-7 7664-39-3	5–18
Ethanolamine	141-43-5	3–17
Toluene	108-88-3	1-15
Xylene	1330-20-7	1-15
Low boiling point naphtha - unspecified - solvent naphtha (petroleum), light aromatic	64742-95-6	1-14
1,2,4-trimethylbenzene	95-63-6	1-10
Surfactant	For instance, 9016-45-9	1-10 non-ionic 2.5 anionic
N-Methyl-2-pyrrolidone	872-50-4	0-10
N,N-Dimethylformamide	68-12-2	0-10
Ammonia	7664-41-7	<10
Benzyl alcohol	100-51-6	2-9
Isobutanol	78-83-1	>0.1-5
Naphtha (petroleum), hydrodesulphurised heavy	64742-82-1	1-5
Non-ionic surfactant	9016-45-9	1-5
(Paraffin) Wax	Various (e.g. 8002-74-2)	1-5
Acetone	67-64-1	~5
Thickener Cellulose methyl ether Cellulose ether Methylhydroxy-ethylcellulose Hydroxy propyl methyl cellulose	Various 9004-67-5 9004-65-3	<5 0-5 2.2 ~2 <2
Phosphoric acid	7664-38-2	<5
1-Methoxy-2-propanol	107-98-2	>0.1-5
n-Butyl alcohol	71-36-3	1-3
White spirit	64742-88-7	< 3
Industrial methylated spirit		<3
2,2,6,6-Tetramethylpiperidine 1-oxyl	2564-83-2	2.57

Table 2.11: Example Components of DCM-based Paint Strippers

Components	CAS Number	Concentration in formulations
Sodium N-alkyl benzosulphonate	68411-30-3	0-2.5
Oxalic acid diethylester	95-92-1	9-2.5
Fatty alcohol ethoxylate		<2.5
Pure turpentine oil	8006-64-2	<2
n-Butyl acetate	123-86-4	1
Sodium nitrite	7632-00-0	<1
Mesitylene	108-67-8	<1
Corrosion inhibitor		<0.5
Sodium chromate	7775-11-3	0.3
Dimethyl glutarate	1119-40-0	No data available
2(2-buthoxyethoxy)ethanol	112-34-5	No data available
Dimethyl adipate	627-93-0	No data available
Naphtha (petroleum), hydrotreated heavy	64742-48-9	No data available
Trichloroethylene	79-01-6	No data available
Potassium hydroxide	1310-58-3	No data available
Sodium hydroxide	1310-73-2	No data available
Propan-1,2-diol	57-55-6	No data available

Source: Consultation

Differences in Composition for Products Marketed in Different Countries

DCM-based paint stripper manufacturers were asked to indicate whether they market the same products in different countries with a different composition. All 12 responding companies indicated that the composition of their products is identical in all markets they are supplied to. Two important points made by two companies were:

- "*No, we have common formulations across the world, there will be local raw material name variations due to local sourcing but every manufacturing site should follow the core recipe. Variants are given different codes to differentiate them…Our aerospace customer base would not allow differing formulations under the same brand name.*"

- "*No, there are no differences in the composition of our products because of the receiving countries. Changes are induced by special problems of our customers.*"

It is understood that the aerospace industry requirements are very specific and strict. With regard to other professional and consumer applications, the situation may be considerably different. The ETVAREAD report (2004) suggests that, in many cases, the same product is distributed in one market under many different brand names (e.g. one product is sold in one Member State under more than 30 different names). ETVAREAD argues that this shows that on a formulation basis, the product diversity per country is comparatively low. We have not obtained information from consultation to support or not this assertion.

2.3.6 Size of Containers for DCM-based Paint Strippers

Table 2.12 presents the available data on the prevalence of different container sizes under the three broad use categories for a number of European countries. Overall, the most widely used sizes are 25L for industrial uses, 5L for professional uses and 1L for consumer uses (with 0.5L a close second). It should, however, be noted that the data may not be representative for the countries for which information has been collected.

Table 2.12: Overview of Most 'Popular' Container Sizes for DCM-based Paint Strippers in Different Countries

Country	Industrial uses	Professional uses	Consumer uses	Notes
Estonia		2.5L, 5L	0.35L, 1L	Estonian Health Protection Inspectorate, 2006a
Germany	*30L*	*30L*		*Consultation with industry (only two responses – priority given to the larger manufacturer)*
Greece	5L (only size)	5L (only size)	0.75L, 1L	Greek General Chemical State Laboratory, 2006a
Iceland		0.5L (only size)	0.5 (only size)	Icelandic Environment and Food Agency, 2006a
Ireland	5L	1L	0.5L	Irish Health and Safety Authority, 2006a
Italy	70 kg	3-4L	0.75L	Italian Ministry of Health, 2007
Latvia	20L	20L	1L	Latvian Environment, Geology and Meteorology Agency, 2006
Lithuania	0.75L	0.75L	1.1L	Lithuanian Environmental Protection Agency, 2006a
Malta			0.5L	Malta Standards Authority, 2006
Portugal	*1L & 5L*	*1L*	*0.25L*	*Consultation with industry*
Slovenia		1L	1L, 0.75L	Slovenian National Chemicals Bureau, 2007a
Spain	*4L*	*4L*		*Consultation with industry (1 response only)*
UK	*25L*	*5L*	*0.5L or 1L*	*Consultation with industry*
Overall	***25L (5L)***	***5L (1L)***	***1L***	

Source: Consultation

3. HAZARDS AND RISKS FROM DCM-BASED PAINT STRIPPERS

3.1 Hazards from the Use of DCM-based Paint Strippers

3.1.1 Inhalation Exposure and Effects Assessment

The hazard potential of DCM-based paint strippers is not fully apparent from the classification and labelling information (see Table 1.2). In terms of human toxicology, the hazard potential of DCM lies primarily in its narcotic effect and subsequent depression of the central nervous system (CNS) at high concentrations. The acute toxicity of DCM is low and the most important acute toxic effect is on the CNS and elevated carboxyhaemoglobin (COHb) levels. These effects are reversible, however fatalities have been reported on a number of occasions. The typical effects of high exposure to solvents are often of neurobehavioral and cardio-toxicological nature (SCHER, 2005).

SCHER (2005) provides an effects assessment related to the inhalation of DCM and the paragraphs below discussing the effects of DCM are largely based on the summary by SCHER.

Metabolism

DCM is metabolised by oxidative metabolism mediated by the ethanol inducible CYP2E1 leading to formyl chloride which decomposes to carbon monoxide that binds to haemoglobin to form COHb. An alternative pathway involves the conjugation with reduced glutathione catalysed by GSTT1 - the conjugate, S-chloromethylglutathione is highly reactive.

CYP2E1 has a much higher affinity for DCM compared to GST, and is the most important pathway at relevant human exposure levels, whereas the GSH dependent pathway becomes qualitatively relevant at high exposure concentrations. Difference in the metabolism of DCM is assumed to play an important role in the interspecies differences seen in the toxic response (SCHER, 2005).

Once absorbed, DCM will readily become distributed in the body. High concentrations are found in fatty tissue (above all, if exposure to the substance took place under physical strain); however, the substance will not accumulate under normal conditions of exposure since a part of it is exhaled in an unchanged state (Bundesinstitut fur Risikobewertung, 2006a).

Central Nervous System Effects

DCM affects the CNS and causes impairment of behavioural or sensory responses at high concentrations. CNS effects have been reported in humans occupationally and accidentally exposed to high levels of DCM. The LOEL for neurobehavioral changes (vigilance disturbance and impaired combined tracking monitoring performance) in humans was observed at exposure to 690 mg/m^3 (193 ppm) for 1.5 to 3 hours (Putz *et al*, 1979). Winneke (1981) found impaired psychological performance in volunteers following 3-4 hours exposure to 300 ppm of DCM.

Some epidemiological studies have investigated neurophysiological and psychological symptoms in occupationally exposed workers, but no statistically significant increases were demonstrated (Cherry *et al*, 1981; Lash *et al*, 1991; Bukowski *et al*, 1992; Soden, 1993).

Acute studies in animals show that DCM affects the CNS; this is consistent with findings in humans. Narcotic effects were observed in several animal species, including monkeys exposed to 10,000 ppm for up to 4 hrs.

Chronic exposure of gerbils to 210 ppm DCM for three months resulted in changes in neurotransmitter amino acids and brain enzymes. A lower DNA concentration was also reported in the hippocampus and cerebellum, probably due to cell loss (IMM, 1998).

Ischemic Heart Disease and Carboxyhaemoglobin

Carbon monoxide is formed in the oxidative P450-mediated metabolism of DCM. Carbon monoxide binds strongly to haemoglobin as COHb. As the metabolic pathway is saturated at high concentrations, a maximum of <10% COHb in blood is normally reached, although occasionally still higher levels have been measured. Human exposure to 170-700 mg/m^3 (47.6-196 ppm) for 7.5 hours leads to COHb levels of 1.8-6.8% (IMM, 1998).

The formation of COHb most likely produces the cardiotoxic effects that have been seen in some studies. Several epidemiological studies have been performed in order to investigate the relationship between occupational exposure to DCM and cardiovascular disease. These studies were inconclusive. An excess of cardiovascular mortality was reported in one study with exposure of 490-1,700 mg/m^3 (137- 476 ppm), but further follow-up studies did not provide compelling evidence of an increased risk (Ott *et al*, 1983).

Genotoxicity

The mutagenicity of DCM has been investigated in both *in vitro* and *in vivo* test systems. Large inter-species differences in genotoxic response have been reported and effects are only seen at high exposure levels. After inhalation exposure of mice to DCM for 10 days at concentrations of 4,000 ppm, a significantly increased frequency of sister chromatid exchanges and level of chromosomal aberrations in lung and bone marrow cells were reported in mice, whereas no evidence of chromosomal abnormalities was observed in rat bone cells following 6 months of exposure by inhalation for up to 3,500 ppm DCM (SCHER, 2005).

In addition, DNA-protein cross-links were detected in mouse liver at doses ranging from 500-4,000 ppm, whereas no cross-links were detected in mouse lung, suggesting different mechanisms of genotoxicity in the two organs. Increased lung cell proliferations were observed in mouse lung at doses higher than 1,500 ppm following 3 days of exposure. In a series of bacterial mutagenicity tests, the activity of DCM was strongest in *Salmonella typhimurium* TA 1535 modified to express the mammalian GSTT1 gene, indicating a role of GSTT1 in the activation of DCM to its mutagenic metabolite. Mutagenic activity was also reported in wildtype *Escherichia coli* following activation by mouse liver microsomes, a characteristic shared by cross-linking agents in mammalian mutagenicity tests. In Chinese hamster ovary cells and freshly prepared mouse hepatocytes, DCM induced DNA single-strand breaks, an effect not observed in rat hepatocytes. It was concluded that the mutagenic activity most likely was produced by the glutathione conjugate (SCHER, 2005).

No studies regarding genotoxic effects in humans after inhalation exposure to DCM was identified by SCHER. An increased level of chromosomal damage has been reported in workers occupationally exposed for DCM, but this group had a concomitant exposure for styrene, and thus could not be linked to DCM exclusively (SCHER, 2005).

Carcinogenicity

Excess of mortality from cancer has been found in some studies of workers chronically exposed to DCM. The fatalities included elevated risk of cancer of biliary passages and liver (Lanes *et al*, 1990), pancreas (Hearne *et al*, 1987) and brain (Heineman *et al*, 1994). However, there seems to be no consistent pattern in tumour appearance, and the results have not been confirmed when other cohorts were examined (Hearne *et al*, 1990; Lanes *et al*, 1990; Tomenson *et al*, 1997).

The occurrence of biliary cancer is interesting as the GSTT1 enzyme is expressed at a high level in the bile duct cells in humans.

In mice and rats, inhalation of very high levels of DCM significantly increased the incidence of liver and lung cancer and benign mammary gland tumours (NTP, 1986). In B6C3F1 mice, doses at and above 2,000 ppm for 6 hours/day, 5 days/week and 102 weeks significantly increased the incidence of liver cancer compared to historical controls. In male F344/N rat, a statistically significant risk of liver cancer was observed at 4,000 ppm.

The species and organ specificity is anticipated to be linked to the GSTT1 activity. *In vitro* studies show that mouse GSTT1 more efficiently catalyse the conjugation of DCM with GSH than the human form. Furthermore, the enzyme is expressed at a higher level in mouse than in human, making it unlikely that humans have sufficient capacity to activate DCM for this compound to be considered to represent a carcinogenic risk (Sherratt *et al*, 2002).

Based upon the current evidence, DCM was classified by IARC as a group 2B carcinogen, in the European Union as a Carc. Cat. 3, and by the US EPA as "*reasonably anticipated to be a human carcinogen*" (SCHER, 2005).

3.1.2 Dermal Exposure and Effects Assessment

In addition to inhalation, DCM can also be absorbed through the skin. The permeability rate in viable human skin was determined to be 24 $g/m^2/h$ (Ursin *et al*, 1995). SCHER (2005) notes that exposure via inhalation is very important due to the high vapour pressure of DCM; however, dermal exposure should also be taken into consideration.

According to SCHER (2005), wearing of gloves is not sufficient to protect workers, because currently, there is no material available, which can completely resist DCM. Breakthrough times of different gloves can vary considerably, for instance, latex gloves or gloves based on butyl polymers usually have breakthrough times between 2 and 8 minutes (Rühl, 2003). SCHER (2005) presents information which shows that only fluoropolymer (fluorocarbon rubber) gloves provide good protection for a time period of up to 150 minutes. However, fluoropolymer gloves are usually not used during paint stripping due to their high costs (around €50 per pair[13]). Therefore, dermal exposure may be considerable. Issues pertaining to the use of personal protective equipment during the use of DCM-based paint strippers are discussed in later Sections of this RPA report.

According to OSHA (2003), skin exposure to liquid DCM may cause irritation or chemical burns. SCHER (2005) also notes that it can be speculated that dermal absorption may be even increased by the presence of the vapour retardants, as they may increase the DCM concentration on the skin.

3.1.3 Susceptible Populations

According to SCHER (2005), a major concern for the toxicity of DCM is the especially susceptible populations. Children are more susceptible due to a potential for higher exposure, as they have a higher ventilation rate than adults and the concentration of DCM may be higher at floor level. Genetically susceptible individuals include persons who are carriers of the unfavourable genotypes of the enzymes involved in the biotransformation of DCM. Furthermore, people with predisposing disease of cardiovascular disease (CVD) may be at a higher risk than healthy individuals, due to the toxicity of carbon monoxide formed by biotransformation of DCM (SCHER, 2005).

The COHb generated from DCM is expected to be additive to COHb from other sources; hence, other groups that may be particularly susceptible are smokers (who maintain significant constant levels of COHb). In addition, higher than normal levels of CO may result when alcoholics are exposed to DCM, since ethanol increases the expression and activity of CYP2E1 (Carpenter *et al*, 1996). Similarly, enhanced expression of CY2E1 occurs in the condition of diabetes, although insulin erases that effect (Thomas *et al*, 1987).

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13 This price may not be accurate for 2007 or for all manufacturers of this type of gloves.

3.2 Assessment of Risks from DCM in Paint Strippers

The risks from DCM in paint strippers have been recently assessed in two Commission funded studied: the TNO report in 1999 and the ETVAREAD report in 2004. Annex C summarises the findings of each report and highlights any comments made by CSTEE and SCHER.

Both reports have concluded that further risk reduction measures are required. According to TNO this applies to all three use categories (industrial, professional and consumer use) while ETVAREAD considered that for industrial uses covered by the VOC Directive no further measures are required.

3.3 Morbidity and Mortality Data Associated with DCM-based Paint Strippers

In the course of this study, information has been collected on accidents associated with the consumer, professional and industrial use of DCM-based paint strippers (morbidity data tend to refer to the first two categories of users only).

Following the completion of the TNO report in 1999, the ECSA Secretariat launched an enquiry among some fifty poison centres across Europe enquiring whether they knew of incidents relating to DCM, especially in three consumer applications: aerosols, adhesives and paint removers. The survey was undertaken in two phases: in phase 1, the response rate was around 20% with the most detailed information received from poison centres in Germany, the Netherlands and Spain. In phase 2 (launched in 2001), ECSA expanded its enquiry by requesting information on chemical alternatives to DCM and by paying for the information, if necessary; the total response rate was around 40%. This time, France and the United Kingdom provided the most detailed information (ECSA, 2002a).

A significant portion of the data presented in Annex E is from the above survey organised by the ECSA. In some countries (Austria, Belgium, Czech Republic, Ireland, Netherlands, Portugal, Slovak Republic and Spain) the poison centres covered the whole country and the replies reflect the national situation. In the other countries, each centre had only a regional coverage (ECSA, 2002a). In general, the absence of incidents with DCM in some countries might be due to deficiencies in the reporting system or to the fact that enquiries were based on trademarks and not chemical substances.

ECSA argues that the number of incidents reported to poison centres related DCM is very limited, especially compared to the number of units of paint stripper sold, and when there are incidents, they are mostly benign. Only very few serious cases are reported, and then they stem mainly from professional use - when the workplace safety standards were not implemented or from other forms of misuse (like ingestion despite warning labels and instructions). ECSA suggests that severe incidents, when they occur, are often due to other hazardous substances accompanying DCM in some paint strippers. For example, the serious skin irritant/corrosive effects may be due to other components, e.g. hydrofluoric acid. However, DCM itself might cause a severely irritant effect if the exposure is occlusive and prolonged, so each case needs looking at carefully and caveats should be applied to any comment.

In addition to the data from the ECSA survey, information was requested from Competent Authorities in the EU-25 + EEA + Switzerland. This, where available, has been included in Annex E and invariably complements the information presented by ECSA.

Overall, the available information on DCM-related incidents is of variable detail with some countries having detailed information while some others do not.

With regard to fatalities relating to the use of DCM-based paint strippers, information has been collated from a number of sources as described in Section E2 (in Annex E) of this report. Efforts have focused on collecting detailed descriptions of each accident so as to establish clearly whether the accident and the ensuing casualties or fatalities are relevant to the study (i.e. have resulted from definitive use of a DCM-based product in a paint stripping operation) as well as identifying and removing any cases of double-counting. However, since access to several original sources was not possible, we have had to rely on descriptions presented in 'second-hand' sources and as a result, cannot guarantee the accuracy of any description in Table E2.1 (in Annex E) which presents the fatalities data.

Table 3.1 provides an overview of the fatalities and injuries relating to the use of DCM-based paint strippers. Some points need to be taken into consideration when using Table 3.1 (and Table E2.1):

- for an accident to be considered as "relevant", the DCM-containing product should have been used in a paint stripping operation. This means that incidents involving cleaning, painting, suicide attempts, etc. are not considered to be relevant to this study;

- for some incidents, their relevance is unclear (as highlighted in Table 3.1) usually due to lack of a detailed description of the conditions under which the accident occurred;

- in most cases, there has been adequate information on which to judge whether the incidents were associated with industrial, professional or consumer use. In some of such cases, an educated guess based on the available information for each incident has been made; and

- in some cases, the date of the accident is not always known.

Table 3.1: Fatal and non-fatal DCM-related Incidents arranged by Location and Relevance (information from literature review for the years 1930-2007 and for both EU and non-EU countries)

Relevance to this study	EU			Non- EU			Unknown location	
	Fatal	**Non-Fatal**	**Location**	**Fatal**	**Non-Fatal**	**Location**	**Fatal**	**Non-Fatal**
Certain	6	6	France	4	0	Australia	2	0
	6	2	Germany	0	1	Israel		
	1	1	Nether-lands	13	21	USA		
	1	0	Spain	1	0	Singa-pore		
	0	12	Sweden					
	1	0	Switzer-land					
	5	36	UK					
Totals	***20***	***57***		***18***	***22***			
Unknown	3	11	Germany	1	3	Australia	0	2
	0	1	Switzer-land	0	1	Israel		
	2	3	UK	1	28	USA		
Totals	***5***	***15***		***2***	***32***			

The table above shows DCM-related incidents resulted in a total of 20 fatalities and 57 non-fatal injuries in Europe. A further 5 fatalities and 15 injuries were also reported for Europe, however, their relevance to this study is uncertain due to the lack of detailed information. Therefore, on the basis of the available information, DCM-based paint strippers may have been involved in a total of 25 fatalities and 72 non-fatal injuries in Europe to date.

Taking into account only accidents that have occurred in the last 26 years (since 1980) - on the assumption that since then, reporting of accidents might have been more consistent and complete[14], the total number of (certain) fatalities in the EU is 19 and the number of non-fatal injuries is 45 (i.e. only 1 death and 12 non-fatal injury occurred before 1980).

With regard to the incidents of unclear relevance to DCM-based paint strippers, since 1980 there have been 5 deaths and 13 non-fatal accidents (i.e. only 2 non-fatal accidents occurred before 1980). In all, since 1980, the total number of deaths and non-fatal accidents may be as high as 24 and 58 respectively (from the available information).

14 It is not clear that all accidents relating to DCM-based paint strippers, even since 1980, have been registered and correctly attributed to DCM.

Table 3.2 below shows the split of these incidents between the three broad use categories of DCM-based paint strippers.

Table 3.2: Overview of Fatalities and Non-Fatal Injuries in Europe between 1930 and 2007 (Literature data – Certain relevance to this study)			
Use category	**Fatalities**	**Non-fatal injuries**	**Location and time of fatalities**
Industrial use	9	6	FR: 3 (1997, 2002, 2007) DE: 1 (2000) ES: 1 (2000) UK: 4 (1989, 1999x2, 2006)
Professional use	9	26	FR: 2 (1990, 1992) DE: 5 (1989x2,1990, 1999, 2002) CH: 1 (1996) UK: 1 (2002)
Industrial/Professional use	0	10	-
Consumer use	2	14	FR: 1 (1993) NL: 1 (1960)
Totals	**20**	**56**	

All 20 relevant fatalities in Europe appear to have involved one or more of the factors presented in Table 3.3 (a single death may have involved more than one factor).

Table 3.3: Factors Contributing to Fatalities in Accidents involving DCM-based Paint Strippers in Europe (1930 – 2007, accidents of certain relevance to this study).		
Factor potentially contributing to fatality(ies)	**Number of incidents**	**Number of fatalities**
Inadequate ventilation	19	14
Inadequate personal protective equipment	9	9
Use of tanks (occasionally open tanks)	9	9
Heat-related accidents[15]:	2	3
(Possible) alcohol abuse	1	1
Long-term exposure	1	0
Unknown reasons	5	1
Source: Data in Table E2.1, Annex E		

These figures are based on the information currently available to us; it is possible that other factors may have played a role in any incident reported in Table E2.1. Moreover, it is generally not possible to indicate which factor was the most 'critical' or 'most important'.

Please note that almost all information[16] on accidents and fatalities (discussed in this Section and Annex E) has been provided by third parties (such as EASCR and the UK formulators group) and open literature (such as ETVAREAD (2004) and OEHHA (2000) as well as journal articles and abstracts); it has not been able to independently verify all sources during the course of this study and as, such, we are therefore not in a position to vouch for the accuracy and interpretations provided therein.

[15] The report on the fatal accident in Switzerland in 1996 mentions that the accident took place in a closed space on a warm day, however, weather conditions were not included in the possible reasons for the accident. The 3 deaths mentioned in the bulletpoint above do not include that fatality.

[16] Limited information has been made available directly from authorities/insurance organisations (for instance, SUVA in Switzerland or the French Ministry of Ecology/INRS).

4. EXISTING CONTROLS ON USE AND EXPOSURE TO DCM

4.1 Current EU-wide Legislation - Protection of Workers

4.1.1 Directive on the Protection of Health and Safety of Workers from Risks related to Chemical Agents at Work

Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) lays down minimum requirements for the protection of workers from risks to their safety and health arising, or likely to arise, from the effects of chemical agents that are present at the workplace or as a result of any work activity involving chemical agents.

In accordance with Article 4 of the Directive, the employer must determine whether any hazardous chemical agents are present at the workplace and assess any risk to the safety and health arising from their presence, taking into consideration:

- their hazardous properties;
- information on safety and health provided by the supplier;
- the level, type and duration of exposure;
- the circumstances of work involving such agents, including their amount;
- any national occupational exposure or biological limit values;
- the effect of preventive measures taken or to be taken; and
- the conclusions to be drawn from any health surveillance already undertaken.

The employer must ensure that the risk is eliminated or reduced to a minimum, preferably by substitution (replacing a hazardous chemical agent with a chemical agent or process which is not hazardous or less hazardous). Where the nature of the activity does not permit risk to be eliminated by substitution, the following protection and prevention measures must be taken, listed in order of priority:

- design of appropriate work processes and engineering controls and use of adequate equipment and materials so as to avoid or minimise the release of hazardous chemical agents;
- application of collective protection measures at the source of the risk; and
- application of personal protection measures.

The employer must regularly measure chemical agents which may present a risk to workers' health, in relation to the occupational exposure limit values. Where an occupational exposure limit value effectively established on the territory of a Member State has been exceeded, the employer must immediately take steps to remedy the situation.

It is of note that, as a general rule, workers who exercise their occupational activity in a manner which does not involve an employment relationship with an employer or, more generally, does not make them subordinate to a third person ('self-employed workers') are not covered by the Community Directives on health and safety at work, in particular framework Council Directive 89/391/EEC. Moreover, these workers are not covered in certain Member States by the legislation applicable in the field of health and safety at work. Nevertheless, self-employed workers, irrespective of whether they work alone or with employees, may be subject to health and safety risks similar to those experienced by employees[17]. This also applies to the use of DCM-based paint strippers by self-employed workers in professional applications.

4.1.2 Use of Personal Protective Equipment Directive

Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace (third individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) lays down minimum requirements for the assessment, selection and correct use of PPE. The term means all equipment designed to be worn or held by the worker to protect him against one or more hazards likely to endanger his safety and health at work, and any addition or accessory designed to meet this objective.

According to the Directive, PPE shall be used when the risks cannot be avoided or sufficiently limited by technical means of collective protection or by measures, methods or procedures of work organisation (Article 3). All PPE must (Article 4):

1. be appropriate for the risks involved, without itself leading to any increased risk;
2. correspond to existing conditions at the workplace;
3. take account of ergonomic requirements and the worker's state of health; and
4. fit the wearer correctly after any necessary adjustment.

Article 5 requires that the employer analyses and assesses the risks which cannot be avoided by other means as well as the conformity of PPE to this Directive before choosing the appropriate PPE.

4.2 Current EU-wide Legislation – Protection of Workers and Consumers

4.2.1 Classification, Packaging and Labelling of Preparations Directive

Current Legislative Requirements for the Packaging of DCM-based Paint Strippers

Further to the classification and labelling of DCM under Directive 67/548/EEC (discussed in Section 1.1 of this report), the Classification, Packaging and Labelling of Preparations Directive (1999/45/EEC) includes provisions on the packaging of DCM-based paint strippers.

17 Text from the preamble to Council Recommendation 2003/134/EC of 18 February 2003 concerning the improvement of the protection of the health and safety at work of self-employed workers.

According to Annex IV (Special Provisions for Containers Containing Preparations Offered or Sold to the General Public) Part A (Containers to be fitted with child-resistant fastenings), containers of whatever capacity containing either methanol at a concentration above or equal to 3% or DCM at a concentration above or equal to 1% which are offered or sold to the general public are to be fitted with child-resistant fastenings.

Also, according to Part B of the same Annex (Containers to be fitted with a tactile warning of danger), containers of whatever capacity, containing preparations offered or sold to the general public and labelled as very toxic, toxic, corrosive, harmful, extremely flammable or highly flammable in accordance with Article 10 and under the conditions laid down in Articles 5 and 6 of this Directive, are to carry a tactile warning of danger.

The child-resistant fastenings must conform to the technical specifications given in Parts A and B of Annex IX to Directive 67/548/EEC. According to this Annex, child-proof fastenings used on reclosable packages (which are relevant to DCM-based preparations) shall comply with ISO standard 8317 (1 July 1989 edition) relating to "Child-resistant packages - Requirements and methods of testing for reclosable packages" adopted by the International Standard Organisation (ISO).

Information from Consultation

The use of "spill-proof containers" for reducing losses of DCM has been highlighted by a number of companies; it is, however, considered this term is used by the companies to describe (narrow-neck) child-proof fastenings on containers that simply comply with national legislation transposing and implementing Directive 1999/45/EC, as described above. Seven companies, located in Greece, Ireland, Portugal (3 companies), and the UK, have specifically pointed out that their products are sold with child-resistant fastenings. A further company notes that only 71% of its production is sold in "spill-proof containers" (again, it is very likely, that the company actually means child-proof narrow-neck container). It is unclear why not all products are in child-proof containers.

Role of Child-proof Containers in the Control of Exposure

Undoubtedly, these child-proof narrow-neck containers, apart from preventing accidents involving children mis-handling the container, they can also reduce the release of the contents if the container is tipped over and can further reduce the release of vapours if the container is left uncapped. It has been suggested by a UK manufacturer of DCM-based paint strippers that these narrow-neck containers are preferred to lever lid container systems (typically found in paint products) commonly used in other parts of Europe; however, with the exception of one company which clearly indicated that only 71% of its tonnage is supplied in narrow-neck containers, no other manufacturer indicated the use of lever lid containers.

Other potential types of spill-proof mechanisms have been suggested such as containers having optic style closures that release a measured volume of stripper at one time or valve closures that would release product only up to a certain angle of pouring. These options have been identified by a UK manufacturer according to whom these are only "*a discussion point and cost and feasibility would have to be looked at*".

Although preferable to lever lid containers, narrow-neck containers do not allow the user to immerse a brush to the product (as small sizes - 0.5 litre or 1 litre - are quite commonly used). As a result, the user needs to decant the contents (or part thereof) of the container into a tub or bucket or a jar. The pouring action will unavoidably break the protective 'skin' created by the vapour retardant and user exposure will occur. Similarly, when the user re-immerses the brush into the tub/bucket/jar for a new application of the paint stripper, the 'skin' will again be broken and exposure to DCM vapours will ensue. There is also the difficulty of returning any leftover stripping material into a narrow-neck container (as opposed to lever lid containers).

It has been argued by a manufacturer of an alternative formulation that because of the use of the narrow-neck child-resistant fastening (which prevents the immersion of a brush and requires the user to decant the product) "*the highest exposure to DCM in paint stripping is during the time of de-canting and application onto the surface*". A manufacturer of DCM-based paint strippers, however, believes that users understand the hazards associated with DCM due to the instructions and advice provided by manufacturers and this would impact on such exposure. Notably, the measurements in the ETVAREAD report did not include measurements of vapour concentrations during the decanting phase of the application process.

In general, it may be concluded that child-proof narrow-neck containers are preferable to lever lid containers in preventing children-related accidents, 'passive' exposure (when the container is not handled by the operator, especially if it is left uncapped) and accidental spillage (when the container is tipped over). However, they may be considerably less effective in reducing exposure associated with the actual stripping process and the normal actions of the user (i.e. decanting its contents, using the brush on the substrate, scraping the paint stripper and the coating off the surface, etc.).

4.3 Current EU-wide Legislation – Protection of the Environment

4.3.1 Integrated Pollution Prevention and Control Directive

The purpose of the IPPC Directive (96/61/EC) is to achieve integrated prevention and control of pollution arising from the activities listed in Annex I to the Directive. It lays down measures designed to prevent or, where that is not practicable, to reduce emissions in the air, water and land from these activities, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole. The relevant categories of activities to this study appear to be presented under point 6.7 of Annex I: installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tonnes per year. These threshold limits mean that not all installations involved in these activities may fall under the provisions of the Directive.

Chlorine and its compounds fall under the provisions of the Directive with regard to their emissions to air as per Annex III to the Directive (Indicative List of the Main Polluting Substances to be taken into account if they are Relevant for Fixing Emission Limit Values).

For the better implementation of the IPPC Directive in relation to the installations falling under point 6.7 of Annex I, the European IPPC Bureau finalised in January 2007 the Reference Document on Best Available Techniques on Surface Treatment using Organic Solvents.

4.3.2 European Pollutant Release and Transfer Register

Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC established an integrated pollutant release and transfer register at Community level (European PRTR) in the form of a publicly accessible electronic database and lays down rules for its functioning, in order to implement the UNECE Protocol on Pollutant Release and Transfer Registers and facilitate public participation in environmental decision-making, as well as contributing to the prevention and reduction of pollution of the environment. DCM is included in the list of pollutants to be reported by an operator if a threshold value is exceeded as defined in Annex II to the Regulation. For DCM, the threshold for emissions to air is 1,000 kg/yr and the threshold for emissions to water and land is 10 kg/yr.

4.3.3 Solvent Emissions Directive

Directive 1999/13/EC (the Solvent Emissions Directive, also known as the VOC Directive) is aimed at preventing or reducing the direct and indirect effects of emissions of volatile organic compounds into the environment, mainly into air, and the potential risks to human health, by providing measures and procedures to be implemented for the activities defined in Annex I to the Directive (adhesive coating; coating activity; coil coating; dry cleaning; footwear manufacture; manufacturing of coating preparations, varnishes, inks and adhesives; manufacturing of pharmaceutical products; printing; rubber conversion; surface cleaning; vegetable oil and animal fat extraction and vegetable oil refining activities; vehicle refinishing; winding wire coating; and wood impregnation, wood and plastic lamination), in so far as they are operated above the solvent consumption thresholds listed in Annex IIA to the Directive.

According to Article 5(8), for discharges of halogenated VOCs which are assigned the risk phrase R40 (DCM is one of them), where the mass flow of the sum of the compounds causing the labelling R40 is greater than, or equal to, 100 g/h, an emission limit value of 20 mg/Nm^3 should be complied with. The emission limit value refers to the mass sum of the individual compounds.

All installations shall comply with: (a) either the emission limit values in waste gases and the fugitive emission values, or the total emission limit values, and other requirements laid down in Annex IIA; or (b) the requirements of a national reduction scheme as specified in Annex IIB to the Directive. The final deadline of compliance is 31 October 2007.

Directive 2004/42/EC (on the limitation of emissions of VOCs due to the use of organics solvents in certain paints and varnishes and vehicle refinishing products), which amended the Solvent Emissions Directive, considers paint stripper as a subcategory of vehicle refinishing products (‘*preparatory and cleaning products*’).

In general, it can be acknowledged that the Solvent Emissions Directive has resulted in a general drive away from chlorinated solvents where this is technically and economically feasible for industry (and this may relate to the declining trends in the sales of DCM in the EU discussed in Section 2.1.3).

4.3.4 Water Framework Directive

On 17 July 2006, the Commission adopted a proposal for a Parliament and Council Directive on environmental quality standards in the field of water policy. That Directive is intended to implement Article 16 of the Water Framework Directive (2000/60/EEC) which requires the Commission to come forward with environmental quality standards (EQS) in surface waters for “*priority substances*”. Dichloromethane is one of the 33 substances classified as such by Decision 2455/2001/EC.

The proposed EQS value for dichloromethane is 20 µg/l as an annual average value for all surface waters. As for all the other priority substances, Member States could define “*transitional areas of exceedance*” around the points of discharge.

In the absence of extensive and reliable information on concentrations of priority substances in biota and sediments at a Community level and in the view of the fact that information on surface waters seems to provide a sufficient basis to ensure comprehensive protection and effective pollution control, no EQSs were proposed for these two environmental spheres. Instead, the proposed directive would require Member States to ensure that there is no increase in concentration in these spheres.

The consequence of the classification of dichloromethane as a priority substance is that adequate combinations of process and product control measures should be taken for the progressive reduction of its discharges, emissions and losses. The impact assessment carried out by the Commission prior to the adoption of the proposal showed that it would be more cost-effective, flexible and proportionate to leave the introduction of additional control measures, including emission limit values, to Member States. Should Member States provide sufficient evidence that additional measures are needed at Community level, there would be various mechanisms under existing and upcoming instruments to allow them to put this to the Commission as a basis for discussion.

4.3.5 National Emissions Ceiling Directive

Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants aims to limit emissions of acidifying and eutrophying pollutants and ozone precursors. This is in order to improve the protection in the Community of the environment and human health against risks of adverse effects from acidification, soil eutrophication and ground-level ozone. The Directive aims to support the protection of humans against recognised health risks from air pollution by establishing national emission ceilings, taking the years 2010 and 2020 as benchmarks, and by means of successive reviews as set out in Articles 4 and 10 of the Directive.

The Directive requires that (Article 4), by the year 2010 at the latest, Member States should limit their annual national emissions of the pollutants sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ammonia (NH_3) to amounts not greater than the emission ceilings laid down in Annex I, taking into account any modifications made by Community measures adopted following the reports referred to in Article 9 of the Directive. Member States shall ensure that the emission ceilings laid down in Annex I are not exceeded in any year after 2010.

The purpose of the Directive is to act as a means of evaluating the Community's progress in the 2004 review of the achievement of interim objectives to reduce overtopping of critical loads and to decide on new ceilings taking into account the thematic strategy on air pollution.

4.4 National Controls on Use and Exposure to DCM

A number of European (EU+EEA+Switzerland) countries have put in place national measures to control the marketing, use and exposure to DCM in paint strippers. While the detailed presentation of the relevant information relating to measures specifically targeting DCM in paint strippers for each country is provided in Annex B to this report, it is worth highlighting the measures taken in the following countries:

- ***Austria***: a ban of sales of DCM-based paint strippers was introduced in Austria in 1992. Notably, DCM-based paint strippers are said to be still available on the Austrian market (Austrian Federal Ministry of Economics and Labour, 2006). CEFIC (2005) also suggests that some professionals still use DCM to manufacture their own paint strippers;

- ***Denmark***: DCM is regulated as a carcinogen under the Carcinogens Directive (2004/37/EEC) as all other substances classified as Carc. Cat. 3. Also, under the Danish legislation on code numbered products, DCM-containing paint strippers get a code number on 5-6 which is the highest number on the scale. Therefore, there is a requirement for substitution by a less hazardous product with a lower code-number that is available on the market (Danish Working Environment Authority, 2006a). Finally, there is a Danish tax on chlorinated solvents;

- ***France***: there has been a suggestion that there is currently in place a prohibition on self-service sales of DCM-based paint strippers to the consumer (the products are kept locked in a cabinet in-store and sales persons need to provide information on their use before selling the products). This has not been confirmed by the French authorities;

- ***Germany***: the Technical Rules for Hazardous Substances (TRGS) 612 provide information on the current state of the art, occupational medicine and hygiene requirements and other established knowledge relating to work with hazardous substances, including classification and labelling. TRGS 612 applies to paint stripping and removal with DCM-based and DCM-free paint strippers. It does not apply to closed systems. According to TRGS 612, DCM-based paint strippers should no longer be used in view of the availability, in principle, and comparable effectiveness of substitute substances and substitute processes. Employers must carry out tests to determine which substitute substance will be most effective in each individual case. If such tests fail (at least three stripping trials with potentially suitable substitute substances), then the use of substitute substances may be deemed technically unsuitable. In Germany, DCM-based paint strippers are not sold in DIY stores, supermarkets etc. but only supplied by specialist paint shops and paint manufacturers who need to supply appropriate information to the user;

- ***Iceland***: DCM-based paint strippers may only be put on the market if they contain a vapour retarding substance/substances in addition to thorough instructions on the use and safety measures. Chemical products (either substances or preparations) are only to be sold in stores and other facilities with a permit from local authorities and are through this subject to regular surveillance (Icelandic Environment and Food Agency, 2006a);

- ***Netherlands***: the use of paints and paint pre-treatment products containing more then 100 g/l of solvents is forbidden. As DCM is a solvent and can be considered as a pre-treatment agent, similar use conditions apply. Moreover, there is a voluntary agreement between the national authorities and industry according to which, after 1 April 2005, DCM-based paint strippers should no longer be used in cleaning operations (graffiti removal);

- ***Sweden***: DCM is prohibited for marketing and use since 1 January 1996 in Sweden as per the Chemical Products (Handling, Import, and Export Prohibitions) Ordinance (1998:944). The Swedish Chemicals Agency has issued a general exception for use in Research and Development or analysis purposes and more than 30 exemptions have been granted in individual cases (Swedish Chemicals Inspectorate, 2006); and

- ***Switzerland***: some deviations from EU legislation are in place but are not expected to have a significant impact on the marketing and use of DCM-based paint strippers.

4.5 Overview of National Occupational Exposure Limits

Table 4.1 below presents the available information on the current occupational exposure limits (OELs) in European countries. In comparison, Table 4.2 provides the relevant limits for a number of non-European countries.

Table 4.1 suggests that 8h-TWA values range between 10 mg/m^3 (in Hungary) and 350 mg/m^3 (in Greece, the Netherlands, the Slovak Republic, Slovenia and the United Kingdom). The short-term exposure limit (STEL) values may be as low as 10 mg/m^3 (in Hungary) or as high as 1,750 mg/m^3 (in Greece and the Netherlands). Hungary appears to be the country with the lowest limit values, values that are lower than 10 ppm.

4.6 Controls of Product Specification – Use of Vapour Retardants

Section D6 in Annex D to this Report discusses the use of vapour retardants in DCM-based paint strippers as a means of reducing exposure.

The key points of this discussion are as follows:

- vapour retardants are predominantly added to the DCM-based formulations with the aim of ensuring that DCM will not evaporate before achieving the removal of the coating, rather than for reducing the exposure of the operator. Naturally, a reduction in exposure (by slowing down the release of vapours) occurs when vapour retardants are used;

- the use of vapour retardants is not a recent phenomenon. Waxes (the most commonly used type of vapour retardant) have been used for decades (since at least the 1940s) and the technology has not changed significantly over the last 20-30 years;

- waxes need to remain undisturbed in order to create a protective film ('skin') which prevents the quick evaporation of DCM from the formulation. When the user interacts with the product (decanting, dipping brush in container, applying paint stripper, removing paint stripper), the 'skin' is disturbed/broken and DCM vapours are released. Some formulators of DCM-based paint strippers have argued that the 'skin' is re-formed very quickly to prevent excess exposure of the user to vapours;

Table 4.1: Overview of Occupational Exposure Limits for DCM in Europe

Country	8h-Time Weighted Average		Short-term Exposure Limit (15 min)		Source
	ppm	mg/mg^3	ppm	mg/mg^3	
Austria	50	175	200 ppm (30 min, allowed twice a shift)	700	Austrian Federal Ministry of Economics and Labour, 2006 (skin notation)
Belgium	50	104	100	210	Arrêté royal du 11 mars 2002 relatif à la protection de la santé et de la sécurité des travailleurs contre les risques liés à des agents chimiques sur le lieu de travail (MB 14.3.2002, Ed. 2; erratum M.B. 26.6.2002, Ed. 2)
Bulgaria		100		517	Decree No. 13 of 30/12/2003 on the protection of workers against the risks of exposure to chemical agents at work
Czech Republic		200		500	Czech National Institute of Public Health, 2006
Denmark	35	122			Danish Working Environment Authority, 2006b (includes a skin notation)
Estonia	35	120	70	250	Riigikantselei, 1998
Finland	100	350	250	880	Finnish National Product Control Agency for Welfare and Health, 2006
France	50	180	100	350	French Ministry of Labour, 2006a
Germany	*"In the latest version of the Technical Regulation on Hazardous Substances – TRGS 900 – Workplace Exposure Limits, the old value of 100 ppm for DCM has been deleted. An updated, and probably lower, limit is under consideration and is expected to be published in 2007"*				BAuA, 2007a
Greece	100	350	500	1,750	Greek General Chemical State Laboratory, 2006b
Hungary		10		10	EMLA, 2000
Iceland	35	122			Icelandic Environment and Food Agency, 2006a
Ireland	50	174	300	1,050	Irish NAOSH, 2002
Italy					No information is available from the Italian authorities
Lithuania	35	120	70	250	Lithuanian Environmental Protection Agency, 2006a
Latvia		50			Latvian Environment, Geology and Meteorology Agency, 2006

Table 4.1: Overview of Occupational Exposure Limits for DCM in Europe

Country	8h-Time Weighted Average		Short-term Exposure Limit (15 min)		Source
	ppm	mg/mg^3	ppm	mg/mg^3	
Luxembourg	"*When there is no EU exposure limit values (Chemical Agents at Work Directive) and in the absence of a German MAK value that could be used as a reference value, we discuss the situation with the concerned parties to agree on a value to be fixed on a case by case basis by a decision of the director of the Labour Inspectorate*"				Luxembourgian Inspection du Travail et des Mines, 2006b
The Netherlands	100	350	500	1,750	SER, 2006
Norway	15	50			Norwegian Pollution Control Authority, 2006
Poland		20		50	ISAP, 2006
Portugal	50	There is no Portuguese legislation concerning OELs for DCM. However there is a Portuguese standard (NP 1796 - Occupational Health and Safety. Occupational exposure limits to chemical agents) which establishes an OEL of 50 ppm (8h-TWA) for dichloromethane, but it is not mandatory.			Portuguese Ministry of Economy, 2007
Slovak Republic	100	350			Slovak Centre for Chemical Substances and Preparations, 2006
Slovenia	100	350	400	1,400	Slovenian Ministry of Labour, Family and Social Affairs, 2006
Spain	50	177			Spanish MLSA, 2006
Sweden	35	120	70	250	Swedish Chemicals Inspectorate, 2006 two notes: the substance easily can be absorbed percutaneously (H) and the substance is carcinogenic (C).
Switzerland	50				SUVA, 2006a
United Kingdom	100	350	300	1,060	UK HSE, 2005 (the HSE and the Health and Safety Commission intend to review these limits)

Note that the Swiss limit has recently been revised and the new limit of 50 ppm will apply from 1st January 2007. The Swiss authorities also noted that a 15-min STEL was never in place in Switzerland, contrary to references made to a STEL in other sources of literature.
The entries presented in italics are from literature and have not been confirmed by the relevant national authorities.
Source: Consultation

Table 4.2: Overview of Occupational Exposure Limits for DCM in Selected non-European Countries		
Country	**8h-Time Weighted Average**	**Short-term Exposure Limit (15 min)**
	ppm	**ppm**
USA (OSHA)	25	125
USA (ACGIH) Recommended	50	
Canada	50	
Mexico	100	500
Australia	50	
Malaysia	50	
Taiwan	50	
Hong Kong	60	
Brazil	156	
Argentina	50	
Colombia	50 (based on ACGIH)	
Source: Dow, 2006		

- products intended for consumer and professional use normally contain vapour retardants. This assertion is based not only in the logic on which these products work (DCM should not evaporate quickly for the paint stripping action to be effective) but also on information collected from companies and Competent Authorities. Only for Slovenia there seems to be a notable discrepancy compared to information from elsewhere, however, the following should be noted: (a) the distinction between users involved in industrial and professional uses is not always clear; and (b) vapour retardants are generally not mentioned in Safety Data Sheets (even for products that are definitely known to contain them) – this does not allow the Competent Authorities to have a clear view of how many products do not contain vapour retardants (especially when the authorities rely on product registers in order to establish which products contain vapour retardants or not);

- non-vapour retarded products are generally used in industrial uses. This does not, however, mean that no vapour retardants are used whatsoever: waxes or other agents (water or plastic balls) may be added in dip tanks to create a protective layer on top. Other cases where a non-retarded formulation is needed include where the paint stripper may be used for cleaning purposes, for instance cleaning the nozzles of spraying equipment. In such cases, the presence of vapour retardant would hinder rather than facilitate the cleaning operation;

- the tests presented in the ETVAREAD report and the available monitoring data suggest that despite the use of vapour retardants, airborne concentrations of DCM during the use of paint strippers may exceed the nationally established OELs; and

- there are parameters perhaps far more important than vapour retardants that influence the exposure of the operator to DCM vapours. These may include: the temperature during application, the dimensions of the treated surface, the dimensions of the room (a room may also be the area around a facade covered with a tarpaulin during the paint stripping operation), and the conditions of ventilation/air exchange during application as well as the competence, experience and working methods of the user.

In summary, while vapour retardants may contribute to the control of exposure of the user to DCM, this contribution is yet unclear (see comments by SCHER (2005) discussed in Section D3.7.1 of Annex D to this report) hence their presence and concentration cannot be used as a reliable criterion for considering a formulation as more or less "safe". Moreover, the existing methods for measuring the evaporation rate of products containing vapour retardants are not necessarily reproducible and have little relevance to real conditions of use of DCM-based paint strippers.

4.7 Current Practices on Engineering Controls

4.7.1 Introduction

Engineering controls are the imposition of structural or mechanical means of protection such as opening up enclosed spaces to the open air to allow for adequate ventilation (top and bottom) or installing local exhaust ventilation to extract vapour with rapid air exchanges or using mechanical ventilation (e.g. fans). The effectiveness of these measures must be tested and verified before the DCM-based product is safely used for paint stripping.

4.7.2 Advice provided by Manufacturers of DCM and DCM-based Paint Strippers

In general, manufacturers do not appear to provide specific advice on what engineering controls should be used, however, they request that adequate ventilation is provided when using these products. Examples of entries in Safety Data Sheets include:

Belgian DCM-based paint stripper manufacturer: "*Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and solvent vapour below the OEL, suitable respiratory protection must be worn.*"

Irish DCM-based paint stripper manufacturer: "*All handling to take place in well ventilated area.*"

Latvian DCM-based paint stripper manufacturer: "*Provide adequate ventilation. If natural ventilation is too poor artificial adequate ventilation must be provided*."

Dutch DCM-based paint stripper manufacturer: "*Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation* *and good general extraction. If these are not sufficient to maintain concentrations of particulates and/or solvent vapours below the relevant occupational exposure limits, suitable respiratory protective equipment should be worn*."

Dutch DCM-based paint stripper manufacturer: "*Adequate ventilation sufficient to control airborne vapour levels well below the MEL/OES values of the various components must be provided. This may necessitate provision of local exhaust ventilation. Monitoring of airborne concentration levels should be used to establish the efficacy of control procedures. Personal respiratory protection should only be used as an emergency control method and is not a substitute for adequate ventilation measures in normal processes.*"

Portuguese DCM-based paint stripper manufacturer: "*Ensure adequate ventilation, if possible with extractor fans at work posts and appropriate general extraction. If this ventilation is insufficient to maintain the concentration of solvent vapours below the exposure limits, wear breathing apparatus.*"

Spanish DCM-based paint stripper: "*Arrange sufficient ventilation by local exhaust ventilation and good general ventilation to keep the airborne concentrations of vapours or dust lowest possible and below their respective threshold limit value*".

UK DCM-based paint stripper manufacturer: "*All handling to take place in well-ventilated area. Provide adequate general and local exhaust ventilation. Must not be handled in confined space without sufficient ventilation*".

UK DCM-based paint stripper manufacturer: "*Provide adequate ventilation. Where reasonably practicable this should be achieved by the use of local exhaust ventilation and good general extraction. If these are not sufficient to maintain concentrations of particulates and/or solvent vapours below the relevant Occupational Exposure Limit values, suitable respiratory protection must be worn*."

Where reference is made to insufficient ventilation, they tend to advise that appropriate PPE be used (see also the Safety Data Sheets of DCM manufacturers, Solvay, 2004 and Arkema, 2007a). Naturally, the employer himself is the only person who may establish in any given situation what type of engineering controls are required on a case by case basis.

4.7.3 Information from Authorities and Other Stakeholders

Examples of advice provided by national authorities are given below.

Advice from the German Federal Ministry of Labour and Social Affairs (TRGS 612)

TRGS 612 recommends that, if the occurrence of high solvent concentrations in the air at the workplace cannot be excluded, then in interior workspaces – particularly when stripping large areas – a good flow of air must be ensured. If no other local means is possible then this should be achieved by mechanical ventilation. When carrying out stripping work in rooms and tanks, it is also important to observe the provisions in Appendix III Nos 1 and 3 of the German Hazardous Substance Regulations (GefStoffV) and in TRGS 507 "Surface treatment in rooms and tanks" (BMAS, 2006).

Advice from the UK Health and Safety Executive

The UK HSE in its guidance to users of DCM-based paint strippers in the furniture refinishing industry suggests that a series of measures are needed for the control of exposure to DCM, the most important of which is a well-designed ventilation system, including good general ventilation. However, working methods are also crucial as the effect of, for example, lip extraction can be lost if work is done outside the influence of the local exhaust ventilation (UK HSE, 2001).

For brush application of the DCM-based paint stripper, the user should provide good general ventilation (using mechanical fans) and local exhaust ventilation (unless work is infrequent/ intermittent). Small articles could be stripped in a simple purpose-built booth and large articles in a spray booth, if one is available (UK HSE, 2001).

For dip tank application, HSE suggests that all tanks should be fitted with effective local exhaust ventilation. General mechanical ventilation should be installed to provide make up air. This should be designed to operate in conjunction with local exhaust ventilation at the tanks. Where possible, a separate ventilated area should be set aside for drying finished articles. Control in the dipping area will also be improved by enclosing the sides and top of the tank (UK HSE, 2001).

The bath layout should be designed to minimise transfer distances and to allow a linear path through the process. If possible, mechanical lifting gear and workpiece support should be provided for workpiece transfer. Long-handled tools should be used for scraping and bath cleaning. All solvent wet items should be stored within the influence of the local exhaust ventilation or in closed containers which can be opened within the influence of the local exhaust ventilation. Tools should be provided with drip guards (UK HSE, 2001).

A simple pump or syphon system should be used to replenish the bath and to flow stripper over workpieces in the bath so that the operator need not reach into the tank to bale solvent over workpieces. Only one person should work at the stripping bath at a time, minimising solvent disturbance. Heated wash tanks which follow the solvent tank should be kept at the lowest suitable temperature to limit solvent flash-off (UK HSE, 2001).

All tanks should be covered when not in use. To avoid high continuous exposures, workers should not spend all their time on one stage of the process. No one should work alone in an immersion stripping workshop. There should always be someone close by who is able to give assistance in an emergency (UK HSE, 2001).

4.7.4 Experiences of Users

Information has been received from users of DCM-based paint strippers involved in professional applications on the types of engineering controls regularly employed; these are presented below. No information has been obtained on industrial uses.

Table 4.3: Engineering Controls for Risk Management for Professional Uses of DCM-based Paint Strippers	
User and key parameters	**Engineering controls usually employed**
Professional user A • Involved in building maintenance • Stripping paint from various materials, principally timber, stone and plaster. ***Typical annual use***: >500 litres annually ***Employees***: 1,000 (but only a small proportion involved in paint stripping)	"*When required we hire in forced ventilation equipment at approx £60.00 per week & it runs on normal electricity supply*."
Professional user B • Paint removal from building facades ***Method***: brush ***Typical annual use***: 2,500 – 3,000 litres ***Employees***: 6	"*Not used in enclosed tanks. Sheeted scaffold with unobstructed air flow.*"
Professional user C • Removal of external coatings from buildings ***Method***: brush or airless spray to soften the coating and then 120°C steam cleaner to remove paint ***Employees***: 5	"*When stripping paint with any paint stripper the building is always scaffolded, this is not always essential for access but mainly to monoflex the work area, this is a tough plastic sheeting that is clipped to the outside of the scaffolding which forms a cocoon to work in.* *Hessian cloth is laid at ground level to collect all the paint debris but still allows the water to drain through to stop the ground becoming water logged.*"
Professional user D • Stone restoration, façade stripping ***Method***: brush to soften the coating and then steam cleaner to remove paint ***Typical annual use***: 1,500 litres ***Employees***: team of 3 employees per job	"*We have been operating for 20 years using DCM based products and have never had any accidents or incidents either from the caustic action of the products or the solvent fumes they generate. This is due to the circumstances within which we use the products i.e. on well-ventilated building scaffolds etc. We are aware of the potential dangers of fume build up and would never use the products in a confined space without ensuring excessive ventilation took place. We very rarely work in enclosed spaces - when we have we either use air fed helmets or use forced air ventilation with large axial fans or compressors- or a combination.*"
Source: Consultation	

4.7.5 Analysis of Current Practices

It appears that with regard to engineering controls that may be used to control exposure to and risks from DCM during the use of DCM-based paint strippers, the following possibilities generally exist

a) *natural ventilation*, which is usually applied at outdoor applications and in well ventilated (draughty) spaces; and/or

b) *artificial ventilation* (by draining off vapours or venting with fresh air), which may be applied in spaces with little natural ventilation possibilities. Mobile ventilation machines (plainly made of a ventilator mounted on small two-wheel chassis and large diameter flexible tube) can be lent from tool supplying centres and are commonly available at, reportedly, low fees.

There is currently not adequate information on the practices in industrial installations with regard to use of engineering controls. While it can be assumed that the requirements and measures that may be taken are more specific for industrial uses (i.e. local exhaust ventilation, forced ventilation, lip tank ventilation, etc.), it is not possible to ascertain the levels of compliance at present. It is important, however, to note that, as shown in Table 3.2, a significant proportion of fatalities associated with the use of DCM-based paint strippers in Europe over the last 26 years was linked to industrial uses with inadequate ventilation and use of dip tanks being among the key parameters contributing to the accidents

With regard to the professional uses of DCM-based paint strippers, the advice given by manufacturers (which is the advice most likely to be read by professional users as it should always accompany the formulation) is that the user must ensure that "adequate" ventilation is there. This in effect means that the national OELs are respected. Naturally, engineering (also known as technical) controls take precedence over PPE, however, in the case of DCM there is a key issue: how do users establish whether the national OELs are not exceeded? It is highly unlikely that those involved in professional uses (especially micro-enterprises of 2-3 employees) would have such equipment. During consultation with users, not a single company suggested that such equipment is currently in use. It is worth highlighting, however, that when working in the open (on a scaffold etc.), a significant level of air exchange would occur. However, this would depend on the weather conditions, the presence of any factors restricting the airflow (for instance, any plastic sheet placed around the working area), and the quantity of paint stripper used and application method used. In conclusion, unless work in undertaken outdoors under favourable weather conditions, the employer may not always be in a position to judge whether the chosen engineering controls are sufficient, i.e. ventilation is "adequate" and the national OEL is respected.

4.8 Use of Respiratory Protection Equipment

4.8.1 Advice provided by Manufacturers of DCM and DCM-based Paint Strippers

Information in Safety Data Sheets for DCM issued by European manufacturers includes:

- DCM manufacturer: "*In case of emergency or short period of overexposure to DCM vapours cartridge-type respirators are suited (filter AX, identification colour: brown). If prolonged exposure above the air control limit is expected or known, a* *breathing apparatus of the self contained or independent air supply type must be worn. Personnel must be trained and experienced in its use.*"

- DCM manufacturer: "*In case of emissions, face mask with type AX cartridge. Self-contained breathing apparatus in medium confinement/insufficient oxygen/in case of large uncontrolled emissions/in all circumstances when the mask and cartridge do not give adequate protection. Use only respiratory protection that conforms to international/national standards*."

- DCM manufacturer: "*In case of insufficient ventilation, wear suitable respiratory equipment. Mask with specific cartridge (organic vapours) AX. Respirator with combination filter for vapour/particulate (EN 141). High concentrations or prolonged activity: Self contained Breathing Apparatus. Provide self-contained breathing apparatus nearby (for emergency*
- *intervention).*"[18]

On the other hand, some Safety Data Sheets of manufacturers of DCM-based paint strippers (which contain other substances apart from DCM) suggest the following actions:

- German DCM-based paint stripper manufacturer: "*Short-term respiratory filter, filter AX, alternatively independent air supply respiratory equipment*."

- Irish DCM-based paint stripper manufacturer: "*If ventilation is insufficient, suitable respiratory protection must be provided. Wear mask supplied with: Gas cartridge (organic substances).*"

- Latvian DCM-based paint stripper manufacturer: "*Air fed respiratory protective equipment should be worn.*"

- Dutch DCM-based paint stripper manufacturer: "*Air fed respiratory protective equipment should be worn when this product is sprayed if the exposure of the sprayer or other people nearby cannot be controlled to below the occupational exposure limits and engineering controls and methods cannot reasonably be improved*."

- Dutch DCM-based paint stripper manufacturer: "*Sufficient ventilation should be provided to maintain airborne vapour levels below the MEL/OES values for the various components. Where this is not possible, an approved positive pressure self-contained breathing apparatus should be worn. Adsorptive canister type respirators are not generally suitable, as the cartridge will be quickly exhausted*."

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[18] Note that according to the DG Enterprise and Industry Internet site (ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist/ppe.html) a new standard (EN 14387:2004 - Respiratory protective devices - Gas filter(s) and combined filter(s) - Requirements, testing, marking) superseded on 6 October 2005 the standard EN 141:2000 (as well as standards EN 371:1992 and EN 372:1992).

- Spanish DCM-based paint stripper manufacturer: "*This product contains low-boiling point liquids. Any respiratory protective equipment should be air-fed*."

- UK DCM-based paint stripper manufacturer: "*If there is a risk of exposure to high vapour concentrations, use respiratory protective equipment. All PPE, including respiratory protective equipment, used to control exposure to hazardous substances must be selected to meet the requirements of the COSHH Regulations*".

- UK DCM-based paint stripper manufacturer: "*Ensure adequate through-draught ventilation. Headaches, nausea or dizziness indicate that substantially improved ventilation is needed. In confined and unventilated areas use air-supplied breathing apparatus. In practice the smell of ammonia becomes too unpleasant to work in long before there is any risk of effects from the solvent elements of the product.*"

- UK DCM-based paint stripper manufacturer: "*If exposure to hazardous substances identified above cannot be controlled by the provision of local exhaust ventilation and good general extraction, suitable respiratory protective equipment should be worn. Air fed respiratory protective equipment should be worn if exposure of the applicator or the people nearby cannot be controlled to below the MEL and engineering controls or methods cannot reasonably be improved. If exposure cannot be avoided by the provision of local exhaust ventilation, suitable respiratory protective equipment should be use*
- *d.*"

- UK DCM-based paint stripper manufacturer: "*Respiratory protection must be used if air contamination exceeds acceptable level. Supplied-air respirator. Self-contained breathing apparatus. Use respiratory equipment with gas filter, type AX.*"

4.8.2 Information from Authorities and other Stakeholders

Advice from the German Federal Ministry of Labour and Social Affairs (TRGS 612)

TRGS 612 recommends that respirators that provide breathing air from a source independent of the surrounding atmosphere should be used (e.g. fresh-air or compressed-air equipment). Respirators with a filter and breathing hoods with AX filters are generally unsuitable[19] (BMAS, 2006).

The TRGS 612 suggests that German employers must bear in mind, however, that wearing cumbersome PPE, such as respirators that provide breathing air from a source independent of the surrounding atmosphere, should not be a permanent measure if technical or organisational measures, such as the use of less hazardous paint strippers, are feasible. Reference should be made to the wearing time limits specified in the

[19] According to Rühl *et al* (2004), "*since DCM as part of a solvent mixture is not retained by respiratory filter masks, working with DCM requires respiratory protection gear which is independent of the ambient air.*"

"Regulations for the use of respirators" in Employers' Liability Insurance Association standard BGR 190 (BMAS, 2006).

Advice from the UK Health and Safety Executive

With regard to the use of DCM-based paint strippers in the furniture refinishing, respiratory protective equipment is required unless it can be demonstrated that exposure is below the maximum exposure limit (8h-TWA) and does not exceed the STEL over a 15 minute period (UK HSE, 2001).

The respiratory protective equipment should be either:

- a full face mask to EN 136 or BS7355 (type approved) with a type approved AX canister suitable for use with DCM; or

- compressed air supplied equipment. A lightweight air-fed visor may be suitable (this is to be checked with the equipment supplier).

When a compressor is used as the source of supply for breathing air, special considerations are necessary to ensure adequate air supply of acceptable quality.

Advice from the US Occupational Safety and Health Administration (OSHA)

According to OSHA (2003), appropriate respiratory protection varies with exposure levels, as specified in Table 4.4. Employers must choose atmosphere-supplying respirators from among those approved by the US National Institute for Occupational Safety and Health (NIOSH). Employers may provide NIOSH-approved gas masks with organic vapour canisters, but only for use in emergency escape. The canisters must be replaced after each use before the respirator is returned to service.

Advice from the Verband der Chemischen Industrie (VCI - German Chemical Industry Association)

In a 2000 document, VCI advises users of DCM-based paint strippers the following: "*Despite good ventilation, stripping of small areas, immediate collection of stripped off paint residues and closing of paint stripper cans, the exposure limit (100 ppm) is regularly exceeded. Therefore, one must use self-contained respirators at such work places except it is proven without doubt through measurements that for specific paint strippers or through special protection procedures the exposure limit is not exceeded. Filtering masks are not an effective protection. When using respirators, general precaution examination has to be applied to the persons wearing them. If the paint stripping work will last more than 20% of the weekly work hours, a special permission has to be requested from the responsible regulatory body for workplace safety*" (VCI, 2000).

Table 4.4: US OSHA Guidance for Selecting Respirators when Handling DCM	
DCM airborne concentration (ppm) or condition of use	**Minimum respirator required***
Up to 625 ppm (25x PEL*)	Continuous flow supplied-air respirator, hood, or helmet
Up to 1,250 ppm (50x PEL)	(1) Full facepiece supplied-air respirator operated in negative-pressure (demand) mode (2) Full facepiece self-contained breathing apparatus (SCBA) operated in negative-pressure (demand) mode
Up to 5,000 ppm (200x PEL)	(1) Continuous flow supplied-air respirator, full facepiece (2) Pressure demand supplied-air respirator, full facepiece (3) Positive-pressure full facepiece SCBA
Unknown concentration, or above 5,000	(1) Positive-pressure full facepiece ppm (greater than 200x PEL) SCBA (2) Full facepiece pressure (demand) supplied-air respirator with an auxiliary self-contained air supply
Fire-fighting	Positive-pressure full facepiece SCBA
Emergency escape	(1) Any continuous flow or pressure-demand SCBA (2) Gas mask with organic vapour canister
Source: OSHA, 2003 **Respirators assigned for higher airborne concentrations may be used at the lower concentrations* ***PEL: Permissible Exposure Limit - based on an 8-h TWA. The PEL for DCM is 25 ppm*	

4.8.3 Experiences of Users

Information on current practices among users involved in professional uses with regard to the use of respiratory protection has been collected during consultation and is provided below.

Table 4.5: Respiratory Protection Equipment for Professional Uses of DCM-based Paint Strippers	
User and key parameters	**Respiratory protection equipment usually employed**
Professional user A • Involved in building maintenance • Stripping paint from various materials, principally timber, stone and plaster. ***Method***: unknown ***Typical annual use***: >500 litres annually ***Employees***: 1,000 (only a small proportion involved in paint stripping)	"*PPE equipment for using DCM-based paint strippers is full face visor…*"
Professional user B • Paint removal from building facades ***Method***: brush ***Typical annual use***: 2,500 – 3,000 litres ***Employees***: 6	"*We use face visor/mask.*"
Professional user C • Removal of external coatings from buildings ***Method***: brush/airless spray to soften the coating and then 120°C steam cleaner to remove paint ***Employees***: 5	"*The men wear a respirator when applying the chemical.*"

Table 4.5: Respiratory Protection Equipment for Professional Uses of DCM-based Paint Strippers	
User and key parameters	**Respiratory protection equipment usually employed**
Professional user D • Stone restoration, façade stripping ***Method***: brush to soften the coating and then steam cleaner to remove paint ***Typical annual use***: 1,500 litres ***Employees***: team of 3 employees per job	"*The men do not use any respiratory protection as the sites we operate on are open to the atmosphere and are fully ventilated naturally.*"
Professional user E • Exterior/interior brickwork, plasterwork, render and delicate metalwork ***Method***: brush ***Typical annual use***: 750 litres ***Employees***: 4	"*We use full face visors*"
Source: Consultation	

4.8.4 Analysis of Current Practices

Overview

Discussions with industry consultees suggest that, concerning respiratory protection against DCM-vapours, the following possibilities exist generally:

- ***use of filter masks (with cartridge filter AX)***, which may additionally be used in case of low natural or artificial ventilation. Filters offer only protection over a rather short period of time depending on the capacity of the cartridge; and

- ***use of masks with artificial breathing air supply***. This has to be applied in confined areas (tanks, basins, closed rooms) where ventilation is not possible. Such PPE can also be lent from tool supplying centres, but usually the specialised companies which do such jobs (should) own appropriate equipment like self-contained breathing apparatus or breathing mask with external air supply and have qualified staff.

Usability and Appropriateness of Filter Masks

<u>Usability of AX Filter Masks according to a Manufacturer</u>

As shown above, AX filter masks are mentioned whenever there is a recommendation for use of a filter mask when working DCM-based paint strippers (and DCM).

A copy of the technical data sheet for an AX filter by a known manufacturer (MSA AUER – AX-Atemfilter) was provided for this study. This filter complies with European Standard EN 371. The filter is indeed marketed as appropriate for use to protect from DCM vapours. However, the substance belongs to the 'first group' of 'low boiling point compounds' (i.e. those organic substances with a boiling point below 65°C). According to the manufacturer, at a concentration of 100 mg/m^3 (i.e. 100 ppm), the maximum duration of use is only 40 minutes. At concentrations of 500 ppm, the maximum duration is reduced to 20 minutes. Most importantly, the manufacturer clearly states "*Use of AX filters against mixtures of low boiling point compounds or mixtures of low boiling compounds and other organic compounds is not permitted because desorption effects may occur*." Methanol is also a 'low boiling point compound' (first group). Evidently, the manufacturer advises against the use of these filters when the user is exposed to the sort of vapours that are released when DCM-based paint strippers are used.

It is understood that, as the retain capacity of filters is measured for pure chemicals only and mixtures of vapours are not tested (as the quantitative composition of vapours depends on the individual case), no filter supplier will grant quantitative figures or an outright permission for a user to use the equipment regardless of what formulation is in use. An AX filter will of course retain the different solvent vapours until its gross capacity is exhausted, before the phenomenon of desorption starts.

The Arguments of a Manufacturer of DCM

On the other hand, a DCM producer has made the case that for most DCM-based paint strippers the only relevant compound is DCM as it constitutes the major compound (80-95 %) of the liquid/paste and is the most volatile one, thus the vapour consists basically only of DCM and filters AX are totally applicable at the conditions during use. This is evidently a generalisation as formulations with much lower DCM concentration (as low as 60%) have been identified.

The Suggestions of Industry and Authorities

Among all Safety Data Sheets for DCM-based paint strippers that have been consulted, only two recommend the use of AX filter masks of which one notes that AX filters may be used for short-term exposures only and the other suggests that X filters are one of several options including air-fed respirators. A third Safety Data Sheet recommends the use of organic filter and this could possibly imply the use of AX filters. The remaining Safety Data Sheets recommend the use of respirators when exposure cannot be controlled with engineering/technical measures.

On the other hand, the available information from authorities (Germany, UK, US) shows that the authorities recommend the use of independent air supply respirators, although the UK HSE does mention AX filter cartridges.

Conclusion

The overall conclusion is that, for paint strippers with such complex solvent mixtures, filters have only a limited capacity and do not offer protection in all cases but generally in low contaminated atmosphere for a limited period of time. Only the manufacturers of the filters can provide definitive advice on whether their products are suitable for use and for how long as long as they know the composition of the preparations; however, since there exists a plethora of formulations based on DCM which may include several organic solvents, filter manufacturers cannot guarantee the effectiveness of their products.

Therefore, filter masks cannot be considered to be a reliable option for effective control of exposure to DCM during the use of paint strippers.

Usability and Appropriateness of Independent Air Supply Respirators

In contrast to AX filter masks, independent air supply respiratory protection devices should work at almost all conditions, even if there is only vapour and no oxygen around. However, it may not always be possible to use such equipment. The Berufsgenossenschaft der Bauwirtschaft (2006b) argues that the respiratory equipment that is recommended by the German TRGS 612 (see BMAS, 2006 and also discussion above) as appropriate (independent air supply respirator) can only be used by healthy and athletic persons. Therefore, an investigation is necessary before its use, as it also happens with fire-fighters who use similar equipment. It is, therefore, possible that for some of the users of DCM-based paint strippers this sort of respiratory protection equipment may not be suitable.

Berufsgenossenschaft der Bauwirtschaft (2007) has advised that they have analysed data on the medical clearance that users need to have before they use an independent air supply respirator to protect themselves from DCM vapours. In 2005 and 2006, Berufsgenossenschaft der Bauwirtschaft examined 1,111 persons to establish their fitness for use of such equipment (these were not workers using paint strippers). 64% passed the exam while 36 % had problems and they were not allowed to use this respiratory protection equipment.

Nevertheless, from an effectiveness point of view, independent-air supply respirators appear to be the most suitable form of respiratory protection equipment when ventilation is not adequate.

Comparison of User Practices and Available

From the responses of the professional users it appears not only independent air supply respirators are not used, in several cases, no real respiratory protection is provided to the user (only a visor that protects from splashes on the face and eyes but very limited protection from inhalation of DCM vapours). This may not be adequate in all circumstances and definitely not appropriate for use of DCM-based paint strippers in cases of limited ventilation where airborne concentrations of DCM vapours may be considerably high. It is important to note that as shown in Annex D (see information in ETVAREAD report and Rühl *et al*, 2004), even when paint stripping is undertaken outside, the exposure levels may exceed by far the nationally set OELs. Therefore, outdoor use does not automatically preclude the possibility of adverse effects.

Working habits have an important role to play in the practices of users especially those of employees of small and micro-enterprises which more often than not do not have the benefit of the presence and knowledge of a health and safety expert. During discussions with users of paint strippers we were informed that employees may often be reluctant to use respiratory equipment much less complex and uncomfortable than independent air supply respirators, such as masks. Especially on hot days spending hours on a scaffold with a mask on is not particularly pleasant. Moreover, some users are under the impression that masks do not effectively protect them as they block them their sense of smell. It has been suggested that some users prefer not to use any mask so that they may smell DCM and this warns them that the airborne levels of DCM are high and they may need to act accordingly (for instance, stop working for a while, move elsewhere to get some fresh air, etc. However, as shown in Section 1.1, detection of DCM occurs around 530 mg/m^3 and recognition around 810 mg/m^3. These levels exceed several national OELs. Our discussions with some users revealed that they were not aware of the issue of detection and OELs.

Furthermore, although it is a matter for the user to assess the risks and take appropriate action on a case-by-case basis (taking into account all relevant parameters such as ventilation, composition of product, way of application, area/amount used, temperature, indoor/outdoor use, working time needed, etc.), another key issue is that, in practice, the user does not perform measurements on the concentrations and does not exactly know if the national OELs are exceeded. It cannot be said stated for certain that at present the users make informed choices (i.e. follow the advise provided to them by their suppliers) or that in their risk assessments (if the employer undertakes a proper one) they err on the side of caution and opt for a conservative approach (for example, use of independent air supply respirators). Discussions with companies involved in professional uses suggest that a conservative approach is not the norm among users.

4.9 Use of Glove Protection

4.9.1 Standards for Gloves

Protection gloves are categorised by European Norms according to their resistance to mechanical impact (EN 388), chemical impact (EN 374), etc. and have to be marked with pictograms and digit codes as discussed below.

Protection from Mechanical Risks

The relevant European Standard for gloves giving protection from mechanical risks is EN 388: 2003. This standard applies to all kinds of protective gloves in respect of physical and mechanical aggressions caused by abrasion, blade cut, puncture and tearing (Ansell, 2007a).

Protection against mechanical hazards is expressed by a pictogram followed by four numbers (performance levels), each representing test performance against a specific hazard. The 'Mechanical Risks' pictogram is accompanied by a 4-digit code (Ansell, 2007a):

a. Resistance to abrasion: based on the number of cycles required to abrade through the sample glove – Performance Level Rating 0 to 4;

b. Blade cut resistance: based on the number of cycles required to cut through the sample at a constant speed – Performance Level Rating 0 to 5;

c. Tear resistance: based on the amount of force required to tear the sample – Performance Level Rating 0 to 4; and

d. Puncture resistance: based on the amount of force required to pierce the sample with a standard sized point – Performance Level Rating 0 to 4.

Protection from Chemical Risks

The relevant European Standard for gloves giving protection from chemical risks and micro-organisms is European Standard EN 374: 2003 (Ansell, 2007b). The following parameters are assessed (Ansell, 2007b):

- ***penetration***: penetration is the movement of a chemical and/or micro-organism through porous materials, seams, pinholes or other imperfections in a protective glove material at a non-molecular level; and

- ***permeation***: the rubber and plastic films in gloves do not always act as barriers to liquids. Sometimes they can act as sponges, soaking up the liquids and holding them against the skin. It is, therefore, necessary to measure breakthrough times, or the time taken for the hazardous liquid to come in contact with the skin.

The key parameter here is permeation. The 'Chemical resistant' glove pictogram must be accompanied by a 3-digit code. This code refers to the code letters of 3 chemicals (from a list of 12 standard defined chemicals, Table 4.6), for which a breakthrough time of at least 30 minutes (= Protection Index Class 2) has been obtained (Ansell, 2007b).

Table 4.6: Standard Defined Chemicals for the Assessment of Chemical Resistance of Protective Gloves (EN 374: 2003)

Code Letter	Chemical	CAS Number	Class
A	Methanol	67-56-1	Primary alcohol
B	Acetone	67-64-1	Ketone
C	Acetonitrile	75-05-8	Nitrile compound
D	Dichloromethane	75-09-2	Chlorinated paraffin
E	Carbon disulphide	75-15-0	Sulphur containing organic compound
F	Toluene	108-88-3	Aromatic hydrocarbon
G	Diethylamine	109-89-7	Amine
H	Tetrahydrofurane	109-99-9	Heterocyclic and ether compound
I	Ethyl acetate	141-78-6	Ester
J	n-Heptane	142-85-5	Saturated hydrocarbon
K	Sodium hydroxide 40%	1310-73-2	Inorganic base
L	Sulphuric acid 96%	7664-93-9	Inorganic mineral acid

Source: Ansell, 2007b

The chemical of relevance to the products being addressed is dichloromethane (Code letter D). According to a manufacturer of DCM, the 'Protection Index' for chemical resistance is a simple classification of the breakthrough time for permeation (diffusion) under test conditions, when the whole glove is almost totally immersed into the test chemical at room temperature:

- Level 1 = minimum 10 min;
- Level 2 = minimum 30 min;
- Level 3 = minimum 60 min;
- Level 4 = minimum 120 min;
- Level 5 = minimum 240 min; and
- Level 6 = minimum 480 min.

Nevertheless, this test does not necessarily reflect the actual protection duration at the workplace. As pointed out by a manufacturer of DCM, it is recommended to use these levels only for comparison and to take in practice only half of the time given above due to the more severe conditions at use, as a glove is also stressed mechanically and by sweat and thus may be weakened.

Several companies manufacturing chemical resistant gloves provide information on the performance of their products. For instance, if the Internet site of Ansell Europe[20] is used to identify suitable gloves to be used with DCM, two options are given to the buyer:

- the 'Barrier' (a 5-layer laminate (EVA), non woven liner) with only 16 min breakthrough time (= Level 1). Chemical resistance: A, B, D. Mechanical resistance: none (like a strong plastic bag); and

- the 'PVA' (a glove with polyvinyl alcohol (PVA) coating) with more than 480 min breakthrough time (= Level 6). Chemical resistance: B, C, D. Mechanical resistance: 3 1 2 1. In addition, this type of glove is sensitive to water (this is a very important consideration).

Another manufacturer, KCL[21], offers a fluororubber glove named 'Vitoject' with more than 120 minute breakthrough time when exposed to DCM (= Level 4). Chemical resistance: D, F, G. Mechanical resistance: 3 1 0 1.

Table 4.7 below summarises the comparison between these three types of gloves in terms of breakthrough time, chemical resistance, mechanical resistance and price per pair.

It seems that PVA has a much better chemical resistance to DCM than either of the other two types of gloves, and equivalent, if not better, mechanical resistance than the Viton

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20 http://www.anselleurope.com/industrial/index.cfm?pages=chemical_intro&lang=EN. Note that the Internet site of this supplier is used due to this accessibility and completeness and this should by no means be considered as an endorsement of his products. The information herein is use for comparison purposes only.

21 http://www.kcl.de/KCLWebEn.nsf/d589385cc73542c8c1256e40003bbd31/cff9c0840544a3d941256981003701c7!OpenDocument

glove (the latter has worse tear resistance). However, it cannot be used where water is present. This is a major drawback considering that steam jets are very often used in paint stripping operations involving DCM-based paint strippers. On the other hand, the EVA laminate is the less costly option but it has no mechanical strength and a short breakthrough time. It is also important to note that the manufacturer states in its website: "*Since Barrier is a glove made of two thin films welded together, dexterity is not optimal*."

Table 4.7: Comparison of Key Glove Materials to Control Exposure to DCM

Material	Breakthrough time	Chemical resistance	Mechanical resistance	Other notes	Price per pair
Barrier – EVA laminate	16 min (Level 1)	A, B, D	No mechanical resistance		€9.60
PVA	>480 min (Level 6)	B, C, D	3 1 2 1	"CAUTION: Do NOT use the gloves in water or water-based solutions."	€25.30
Viton (Vitoject)	120 min (Level 4)	D, F, G	3 1 0 1	Water-resistant	€89.50

Source: Internet sites of Ansell Europe, KCL and Carl-Roth (www.carl-roth.de/) for prices per pair of gloves
Note: Depending on the source of supply there may be a large variety in prices. When ordering a larger quantity of gloves, the costs may be substantially lower than for buying a single pair; thus the cost indication given above is for comparison only.

Table 4.8 provides a comparison of the above gloves to others widely used by users of chemical substances. The test data discussed in the Table were obtained with commercially available inhibited solvents and cannot be duplicated with mixtures containing more than 5% of another component. It should also be noted that this information was taken from a publication of a DCM manufacturer and the figures quoted may be different to those quote elsewhere (e.g. Ansell Internet site). The table is provided for comparison purposes.

It is of interest that the breakthrough time of the EVA laminate appears to be much longer than the time indicated at the Ansell Europe Internet site. Also, a breakthrough time of 150 min for fluororubber gloves has been suggested in other sources rather than the above quoted 83 minutes (for instance, the TRGS 612), however, the breakthrough time is very dependent on the thickness of the glove, and different thicknesses may explain the difference in these times.

In general, the assessment of the suitability of a particular type of gloves for a given application is undertaken in laboratories against specified parameters. Commercially available gloves made from the same material often vary widely in their permeation characteristics. Some of this variation is the result of different thicknesses, but there are also differences in composition, additives, colorants, manufacturing processes, and other variables from one manufacturer to another (Dow, 1997).

Table 4.8: Breakthrough Time for Common Glove Materials exposed to DCM (minutes)			
Duty	**Material**	**Thickness (mm)**	**Breakthrough time in min (Permeation rate in mg/sec/m^2)**
Heavy	Viton™ Fluoroelastomer	0.15	83 (3.8)
	Polyvinyl alcohol*	0.45	>480
	EVA Laminate**	0.07	>480***
Medium	Butyl Rubber	0.40	10 (116)
	NBR (Nitrile)	0.34	<1 (938)
	Neoprene	0.48	<1 (447)
Light	Polyethylene	0.07	<1 (70)
	PVC (Vinyl)	0.10	<1

Source: Dow, 1997
** Water soluble.*
*** Three layer laminate: polyethylene (PE)/polyethylene vinyl alcohol (EVAL)/PE.*
**** Test data from manufacturer: Broste Product Report 6827-hf, "Permeation Tests of 4H Glove, 1986," Broste Industry, A/S, DK-1415 Copenhagen, Denmark (1986, 1989 and 1990, and March 1991 letter).*

Some of the parameters which are considered in these tests include (Dow, 1997):

- ***thickness***: the thicker the glove, the longer the breakthrough time and the lower the permeation time;

- ***amount of contact***: this refers to the amount of time in which the gloves are exposed to the substance; continuous immersion in the liquid may be used to represent the worst-case scenario;

- ***type of substance or mixture***: the permeation behaviour of mixtures can be very different from that of the pure components. As a general rule of thumb, the higher the proportion of the component and the smaller and more volatile its molecule, the more important it will be in determining the permeation characteristics of the mixture. DCM-based paint strippers often contain several components, for instance methanol (a small molecule with a significant vapour pressure of 128 hPa at 20°C) at significant concentrations usually exceeding 5%; and

- ***temperatures***: tests are often carried out at room temperature (23°C). An increase in temperature of 10°C generally cuts the breakthrough time in half and doubles the permeation rate. However, DCM-based paint strippers are invariably used at room temperature or lower since DCM has a very low boiling point (30 to 40°C according to Table 1.1).

4.9.2 Advice provided by Manufacturers of DCM and DCM-based Paint Strippers

Advice of Manufacturers of DCM

According to the German manufacturer of DCM, most plastics are attacked, softened or dissolved by DCM or become permeable and loose their integrity. Concrete for constructions and foundations is permeable for chlorinated solvents. To prevent environmental pollution due to leaks or spillage a resistant sealing has to be applied in concerned areas (approved special two-component resin laminates, liner of steel) or a special resistant concrete has to be used (LII Europe, 2002). With regard to gloves, it is suggested that users opt for fluororubber (LII Europe, 2002) or PVA gloves (Solvay, 2004).

Advice and Views of Manufacturers of DCM-based Paint Strippers

The advice given by manufacturers of DCM-based paint strippers is quite variable. Example entries in Safety Data Sheets are given below.

- Belgian DCM-based paint stripper manufacturer: "*For prolonged or repeated contact, use PVA gloves (cat III – EN 374). Barrier creams may help to protect the exposed areas of the skin, they should however not be applied once exposure has occurred*."

- German DCM-based paint stripper manufacturer: "*Chemical resistant gloves. Not suitable: gloves made of thick material. Details of glove material [type, thickness, permeation time/how long should it be worn, cover strength], e.g. Viton rubber 0.7 mm strong, permeation = 480 min. Details of glove material: PVA min 130gr, permeation = 480 min*."
- Irish DCM-based paint stripper manufacturer: "*Protective gloves must be used if there is a risk of direct contact or splash. Use thin cotton gloves inside the rubber gloves if allergy risk. Use protective gloves made of: Nitrile*."

- Latvian DCM-based paint stripper manufacturer: "*It is recommended to wear protective gloves and to use preventive cream.*"

- Dutch DCM-based paint stripper manufacturer: "*When skin exposure may occur, advice should be sought from glove suppliers on appropriate types. Barrier creams may help to protect exposure areas if the skin but are not substitutes for full physical protection. They should not be applied once exposure has occurred*."

- Dutch DCM-based paint stripper manufacturer: "*Wear impervious gloves and check suitability with the glove manufacturer. Most glove types offer limited resistance and should be changed frequently, especially if contamination occurs. It is the Company's experience that the '4H/Silvershield' laminate type gloves manufactured by North Safety Products offer the best resistance, especially when used as an inner or outer glove with other glove types*."

- Portuguese DCM-based paint stripper manufacturer: "*Protective creams may be used for exposed skin, but they should not be applied after contact with the product. In the event of prolonged or repeated contact with the hands, use appropriate gloves*."

- Spanish DCM-based paint stripper manufacturer: "*Wear suitable gloves. Barrier creams may help to protect the exposed areas of the skin, but should not be applied once exposure has occurred. Barrier creams may not be used under or instead of gloves. It is not possible to specify precise type of gloves, since the actual work situation is unknown. Supplier of gloves should be contacted in order to find the appropriate type*."

- UK DCM-based paint stripper manufacturer: "*When skin exposure may occur, advice should be sought from glove suppliers on appropriate types and usage times for this product. The instructions and information provided by the glove supplier on use, storage, maintenance and replacement must be followed. Barrier creams may help to protect exposed areas of skin but are not substitutes for full physical protection. They should not be applied once exposure has occurred*."

- UK DCM-based paint stripper manufacturer: "*Use protective gloves. For short term exposure use protective gloves made of: Polyvinyl chloride (PVC). For longer term exposure wear North Silver Shield Gloves (break through time >8 hours)*."

Apart from information presented in Safety Data Sheets, information has been received from manufacturers of DCM-based paint strippers on the advice they offer to their customers. A German company said "*We have (and sell) E-4Hgloves (EVA laminate) for work with DCM. To be honest, they are not really comfortable but they are safe. Maybe workers like other materials better, but we would not accept this*".

A Portuguese company said "*We advise our customers to wear suitable rubberised gloves and goggles during application. We also provide a series of precautionary instructions with regards to personal safety*".

Finally, at a meeting with a UK formulator of DCM-based paint strippers and a small number of his customers (all involved in professional uses of DCM-based formulations), it was indicated that users are generally advised to use elbow-long PVC gauntlets.

4.9.3 Information from Authorities and other Stakeholders

Advice from the German Federal Ministry of Labour and Social Affairs (TRGS 612)

As explained earlier in this report, TRGS 612 outlines the types of PPE that need to be used when any paint stripper is used. With regard to hand protection during the use of DCM-based paint strippers, the TRGS 612 indicates that protective gloves made from Viton™ (fluororubber) need to be used; these have a maximum wearing time of 150 min. When wearing protective gloves, cotton undergloves are recommended (BMAS, 2006).

Advice from Berufsgenossenschaft der Bauwirtschaft

Berufsgenossenschaft der Bauwirtschaft (2006b) also argues that workers handling DCM must use gloves made from fluororubber. All other glove materials have extremely short break-through times below 8 minutes. Moreover, it reiterates that some materials are sensitive against water (PVA-gloves) or very sensitive against mechanical stress and are not ergonomical (EVA laminate). Of interest is the fact that BAuA (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2006c) also argues that "*EVA-laminate & PVA (4H-Glove) is a 20-year old invention but nobody can work with it in practice because they have no mechanical strength*".

In response to the argument that gloves to be used with DCM-based paint strippers should aim at protecting against splashes rather than immersion of the covered limb into the chemical preparation, the Berufsgenossenschaft der Bauwirtschaft (2006b) maintains that it is impossible to work with paint stripper, without coming in contact with this chemical; "*if a splash is on the glove, at this point of the glove there is a permanent contact. Therefore the selection of the gloves always takes place related to the continuous contact. Or the glove must be taken off immediately, if it comes with the chemical into contact - this is in practice not feasible, however*".

Advice from the UK Health and Safety Executive

With regard to the use of DCM-based paint strippers (in the furniture industry – this is assumed to apply to other industrial sectors as well), the UK Health and Safety Executive (UK HSE, 2001) advises that PPE should be provided and worn as required by the Personal Protective Equipment at Work Regulations 1992. The minimum protective equipment requirements for anyone working with DCM are impermeable overalls, apron, footwear, long gloves and gauntlets and chemically resistant goggles or visor.

Furthermore, the UK HSE issued a publication in 2004 offering advice to workers in the printing industry on health and safety issues (UK HSE, 2004). This document provides a useful overview of the suitability of different types of gloves when working with different solvents.

The UK HSE describes what should be the 'first and second choice' materials for working with a specific solvent. The importance of using a material from the 'first choice' group depends on the extent of the chemical contact. If workers' gloves are significantly contaminated for extended periods then the 'first choice' glove material may be required. If, however, there is only occasional splashing of chemicals onto the glove, then the 'second choice' glove material may be adequate. The UK HSE advises that the extent of exposure will be different in each workplace and should be identified as part of a risk assessment. Other factors, which also must be considered, are the manual dexterity required for the job and how long the glove needs to be (i.e. will gauntlets be necessary). If workers cannot do their job because the gloves are too thick or stiff, then they may decide not to wear them (UK HSE, 2004).

Of greatest importance to this study is the following: according to the UK HSE, for DCM, the 'first choice' is Viton™ and no 'second choice' exists. The UK HSE goes further by stating "*No material will provide more than short-term protection against DCM. For exposures to a combination of DCM and methanol as found in paint stripper, there are no materials to offer more than short-term protection*" (UK HSE, 2004).

4.9.4 Experiences of Users

During consultation, information was received from a small number of users involved in professional applications, all of them based in the UK, with regard to the PPE they use. As far as gloves are concerned, the information is presented below.

Table 4.9: Glove Protection for Professional Uses of DCM-based Paint Strippers

User and key parameters	Gloves usually employed
Professional user A • Involved in building maintenance • Stripping paint from various materials, principally timber, stone and plaster. ***Typical annual use***: >500 litres annually ***Employees***: 1,000 (only a small proportion involved in paint stripping)	"*We use gauntlets and hooded disposable boiler suit.* *When choosing gloves you need to consider the anticipated exposure. We would consider our paint stripping activities to need gloves that give "splash protection" to be adequate as we do not immerse the gloves in the product. Whilst Viton™ gloves would give excellent protection Marigold G25 (nitrile) or similar will provide splash protection at much lower cost.* *The gloves are selected during the risk assessment process as different tasks may require different gloves & personal protection equipment. Advice is normally obtained via the product and glove manufacturers*."
Professional user B • Paint removal from building facades ***Method***: brush ***Typical annual use***: 2,500 – 3,000 litres ***Employees***: 6	"*We use full chemical wet suit, neoprene gauntlet gloves, and knee length protector Wellingtons.*"
Professional user C • Removal of external coatings from buildings ***Method***: brush or airless spray to soften the coating and then 120°C steam cleaner to remove paint ***Employees***: 5	"*The men wear waterproof overalls, Wellington boots and long length rubber gauntlets; these are a standard glove used when handling chemicals available from the shelf from most good stockist.* *Main two ways we apply the chemical are by brush from a bucket or by airless spray, a suction tube is placed into the bucket and pumped up to the spray gun, airless spray minimizes overspray as opposed to air spraying which can cause overspray in the air. We do not decant the product.* *We do not consider it to be hazardous to use steam cleaners with DCM as it is water soluble and diluted considerably during the washing down process*."
Professional user D • Stone restoration, façade stripping ***Method***: brush to soften the coating and then steam cleaner to remove paint ***Typical annual use***: 1,500 litres ***Employees***: team of 3 employees per job	"*The men use PVC waterproof jackets and rubber gauntlets. Once the paint stripper has been applied and left to dwell it is removed by hot water washers (steam cleaners) which can cause spray back - thus the water proof suits.*"

Table 4.9: Glove Protection for Professional Uses of DCM-based Paint Strippers	
User and key parameters	**Gloves usually employed**
Professional user E • Exterior/interior brickwork, plasterwork, render and delicate metalwork ***Method***: brush or airless spray ***Typical annual use***: 750 litres ***Employees***: 4	"*We use PVC waterproof coveralls and PVC gloves.*"
Source: Consultation	

From the above, two key points may be made:

- different companies use a variety of different types of gloves including PVC, rubber, neoprene and nitrile gloves, even where the types of work they undertake are apparently similar; and

- no company uses fluororubber gloves.

The views of different companies seems to vary a lot. Professional user A whose employees use nitrile gloves, believes that these gloves provide adequate splash protection as the hands of employees are not immersed in the paint stripping product. However, he would not recommend PVC gloves even when using alternatives that are less aggressive due to the risk of splitting or perforating whilst in use. On the other hand, other users consulted indicate that they only use PVC gloves.

4.9.5 Overall Assessment of Current Practices

Choice of Gloves: Are Fluororubber Gloves Always Necessary?

The use of a glove must be appropriate to protect at the specific working conditions, which are defined by the following parameters:

- exposure levels (including pathways of contact);
- mechanical work intensity; and
- duration.

How Important is the Mechanical Strength of the Gloves?

Conflicting views have been received on the mechanical stress to which gloves are subjected during normal use of DCM-based paint strippers. It has been suggested, for instance, that the use may involve the climbing of scaffolds and during this process the gloves may be damaged. On the other hand, others have commented that, of course, chemical-resistant gloves are not designed for climbing scaffolds, but ladders or stairs being always installed in scaffolds enabling workers to reach the higher working levels safely and with ease. The operator does not perform construction or demolition works with big sledges or turning heavy controls and instruments, but uses common craftsmen's tools like brushes, scrapers, water jet hoses, buckets, ladders, etc. in simple manners without big mechanical impact.

Nevertheless, it is correct that manual work does take place during paint stripping. Occasionally, users need to put considerable effort in the application of the stripper and its subsequent removal. The substrates are often textured, made of brick, stone and other materials that by virtue of not having a smooth surface may indeed cause damage to the gloves. In conclusion, the mechanical strength of the gloves is an important parameter to be considered.

In this regard, the following three scenarios may be considered:

1. if there is only a simple work to be performed such as application of paint stripper (e.g. brushing or spraying) or washing off with water jet with no broad direct contact (immersion in the liquid paint stripper) and little mechanical impact and a rather small working time (1-2 h, not for a whole day shift) a simple glove like the laminate (Barrier) could be considered to be sufficient;

2. for more severe working conditions like removing stripped coatings manually with scraping tools or finishing with steel wool there is usually direct contact which requires a more robust glove like PVA or fluororubber gloves, although some consultees have expressed concerns on the mechanical strength of PVA gloves; and

3. if water is used for manual mechanical removing of the coating, then only the laminate gloves or the fluororubber gloves are suitable; in case of heavy or long lasting mechanical strain the only choice are fluororubber gloves which offer good mechanical properties, which barrier does not.

Overall, a single user may, in theory, use different gloves for different parts of his work and it is possible that in the course of the day he may encounter conditions which may best endured with one or the other type of glove. However, it is unrealistic to expect that the user would be willing to change gloves half-way; logistically, the use of more than one type of gloves is also far from ideal: companies would need to have a stock of several types of gloves. This may cause problems in professional uses where the packs of gloves would need to be carried around to where paint stripping will take place. Also, buying smaller quantities of several types of gloves rather than a larger quantity of one type only would not allow the company to negotiate a good price with its supplier. Overall, the use of a variety of gloves would make complicate paint stripping work and as shown by the real examples in Table 4.9, companies are happy with just one type of gloves which offers sufficient protection around the year under all circumstances. Therefore, a single choice of protective gloves is believed to be the most appropriate solution to prevent dermal exposure, and the available information points to the direction of fluororubber gloves. The main reasons for this choice are:

- they have very good permeation resistance;
- they have good mechanical properties; and
- they are water-resistant.

Admittedly fluororubber gloves are not the most comfortable gloves in which paint stripping and decorating work may be undertaken. Also, they are considerably more expensive that the alternative types of gloves (laminate and PVA) and even more expensive than what users appear to actually use today (PVC, nitrile, neoprene gloves). However, no other type of gloves can combine the above technical characteristics. Importantly, the use of fluororubber gloves is recommended for use byBoth the German and UK authorities (BMAS, 2006 and UK HSE, 2004) as the only suitable option for paint stripping.

Glove Replacements Rate

Fluororubber gloves may have the best technical characteristics among all types of chemical resistant gloves; however their breakthrough time is limited to 150 minutes[22]. This means that gloves may need to be replaced after prolonged use. However, this breakthrough time of 150 minutes should be treated with caution because:

- this breakthrough time corresponds to a laboratory test which involved immersion of the glove to the chemical agent; normally a user of DCM-based paint stripper will not immerse his hand in a container of the paint stripper and splashes and aerosol will be the main pathways of dermal exposure;
- the gloves are subjected to mechanical stress during use and this affects the breakthrough time;
- similarly, the use may sweat and this also affects the breakthrough time;
- paint stripping formulations contain several components the presence of which may also affect the breakthrough time of gloves; and
- it may not always be possible to know how long a paint stripping job may take or how the individual user may use the gloves.

Overall, it is not possible to establish a universal replacement rate for gloves. And even if such a thing was possible, the working habits of the user would play a vital role: the information that is available from users involved in professional applications suggests that they generally do not use fluororubber or even PVA gloves. Moreover, they appear to have very little regard to the need to replace their gloves on a regular basis. Interestingly, in consultation with users, it was indicated that they may use PVC gloves, usually for days, until the solvent has penetrated the glove to the extent that the glove becomes stiff and working with it is very uncomfortable. Only then the user will replace the gloves with a new pair.

Gloves are indeed a 'costly issue' as they are usually a disposable accessory with (very) limited lifetime (depending on working conditions). Thus such expenses have to be taken into account for calculating the costs for a certain job (of course, this is relevant for paint stripping with any type of paint stripper, as well as painting with solvent-based paints). As commented by a manufacturer of DCM, "*in practice it is often noticed that workers (especially from small or one-man companies) do not use appropriate gloves*

22 We are using here the breakthrough time suggested in the TRGS 612 (BMAS, 612).

due to elementary lack of knowledge or principal unwillingness to spend money for working safety and PPE". It may therefore be assumed that, even if the appropriate type of gloves would be used (fluororubber), the user may still neglect replacing them at regular intervals in accordance with the manufacturer's instructions. In fact, where expensive gloves are used, the user, particularly the small-scale user, may be even more reluctant to promptly replace the gloves in order to avoid the associated cost, the inconvenience and to save time.

Overall, it is not possible to specify a replacement rate for gloves used with DCM-based paint strippers. The employers should contact their glove suppliers to inform them of their working practices and the composition of the formulations they intend to use, and to obtain advice on the rate at which the gloves should be replaced.

4.10 Effectiveness of Existing Risk Reduction Measures

4.10.1 Basis of Analysis

The assessment of the effectiveness of existing risk reduction measures has taken into account:

- the results of the two **previous assessment reports** on DCM in paint strippers, the TNO report (1999) and the ETVAREAD report (2004), which have demonstrated the need for further risk reduction measures;

- the available information on **exposure levels** during consumer (DIY), professional and industrial use of DCM-based paint strippers (where this includes both measurements during actual use of these products and measurements during simulation of paint stripping activities - see details in Annex D to this report) which indicates that;

- the existing **legislation** at the EU and national level on the control of exposure to DCM during the use of paint strippers and its scope (i.e. mainly worker protection legislation (Directive 98/24/EC), the established national OELs and environmental legislation (IPPC/WFD/SED Directives)) and the current levels of compliance of the users;

- the available information on **current practices** among users (in industrial, professional and consumer applications) of DCM-based paint strippers, especially with regard to the use of appropriate ventilation, respiratory protection equipment and gloves;

- the available information on **accidents** (that have resulted in fatalities and non-fatal injuries) associated with the use of DCM-based paint strippers and the conditions under which these appear to have occurred; and

- the **views of stakeholders** (including manufacturers of DCM, manufacturers and users of DCM-based paint strippers and of alternatives, and Competent Authorities in EU+EEA+Switzerland).

On the basis of the analysis undertaken for each of the points above, it is concluded that further risk reduction measures are necessary to prevent accidents that result in fatalities and injuries and to protect the health and safety of the users of DCM-based paint strippers.

The discussion below sets out the key issues for the three broad categories of use.

4.10.2 Industrial Use of DCM-based Paint Strippers

Existing controls: there are existing measures (for instance, workers protection legislation, specific national measures, such as established OELs as well as environment-orientated legislation (VOC/IPPC/WFD)) which set out the framework for adequately controlling directly or indirectly the risks from DCM-based paint strippers to the users. However, the statistics on fatalities and injuries show that this is not always the case. The existing measures, as they stand cannot always guarantee compliance. Nor do they appear to prevent misuse of DCM-based paint strippers and violation of elementary safety measures (issues of ventilation and PPE). Of particular concern is the fact that several accidents are associated with the use of DCM-based paint strippers in what can be described as 'open tank' applications. Issues of enforcement and monitoring are key to the effectiveness of the current legislation.

Size of enterprises and enforcement/compliance issues: smaller/occasional users may be less conversant with the current requirements and thus might not be fully controlling the risks to their health. Smaller companies are less likely to employ someone with expertise on health and safety issues who would be able to advise the workforce and monitor the implementation of the relevant legislation. Moreover, it has also been suggested that enforcement of legislation is occasionally focused on large users which are more prominent and identifiable while many small companies may receive far less attention from the authorities.

4.10.3 Professional Use of DCM-based Paint Strippers

Existing controls: observing OELs, especially in 'open' applications (such as removal of paint from external building walls), is problematic: to date, a single professional user of DCM-based paint stripper who monitors the airborne concentration of DCM during use has not been identified. In fact, we have received enquiries requesting assistance in identifying suitable equipment for such measurements to take place. Without such equipment, it is uncertain whether users indeed take all necessary measures to protect themselves. If such equipment is actually available on the market may well be costly to purchase, particularly by small companies.

More generally, in discussions with companies involved in professional uses, it has emerged that users have limited knowledge of the role and importance of OELs and may have limited knowledge on how to assess the risks from the substance before taking exposure control measures. For large users who may be sub-contracted to larger organisations (a consultee for example has worked for the London Underground on the removal of graffiti), there may be a real need for a detailed risk assessment to be undertaken, documented and submitted to the relevant Health and Safety branch of the larger organisation. However, many users are simply two or three employees working from a small office, using a van to move from one customer to the other without any formal preparation of a risk assessment. A micro-enterprise with 2 or 3 employees most likely will not employ any safety and health expert who would be able to advise on practices and equipment to be used. Moreover, as discussed in Section 4.1.1, matters are less well defined with regard to the protection of the safety and health of self-employed workers. A considerable proportion of those involved in professional uses of DCM-based paint strippers may be self-employed (painters and decorators).

Inappropriate use of PPE: inappropriate and inconsistent use of PPE is also an issue. This may not only be an issue of personal choice of the users but also relevant to the information and advice provided to the user by his supplier. For instance, some suppliers recommend the use of PVC gloves, some others the use of nitrile gloves, and some others the use of butyl rubber gloves or fluororubber gloves. The available information shows that fluororubber gloves should be the choice of the users. Similarly, the information and advice provided in Safety Data Sheets with regard to respiratory protection equipment appears to be at times inconsistent with the technical specifications of the recommended equipment (this is with reference to the issue of the applicability of AX filters).

Mobility of users involved in professional uses: the fact that these users are so mobile is compounded by their large number (for example, it has been suggested that there are around 30,000 decorators in Germany alone); this makes the monitoring of their activities on a regular basis very difficult for national enforcement authorities. Knowledge of the provisions of existing legislation and adherence to them is the responsibility of the employer and not of the enforcing authorities; however, as explained earlier in this sub-Section companies frequently do not have the knowledge or means to adequately protect their employees.

Consumer-like behaviour of those involved in professional uses: another issue is the fact that these users, usually those only occasionally involved in paint stripping may as well behave like consumers and purchase DCM-based paint strippers from a retail outlet (DIY store). In this regard, such a user may be acting exactly like a consumer who receives little technical information on the product and how it needs to be used[23].

4.10.4 Consumer Use of DCM-based Paint Strippers

Enforcement issues: in general, it is impossible for authorities to comprehensibly control the way in which consumers use any given product – even if there was a provision for DCM-based paint strippers to be sold only in conjunction with appropriate

[23] As a manufacturer of DCM-based paint strippers suggested "*a small furniture restorer business might go into a DIY retail store and buy a 5L tin (every month or so) rather than buying direct from a distributor as their volumes would not justify it*".

PPE, the authorities would not be able to enforce the use of such equipment if consumers have reasons not to use it (for example, if the PPE makes the paint stripping process too uncomfortable or complicated).

Availability of appropriate health and safety information: for DCM, it is important to note that, generally (perhaps with the exception of container size), the consumers have access to the exact same formulations of DCM-based paint strippers as tradesmen; however, while the regulator may require the users to assess the risks and subsequently take adequate measures (engineering controls, PPE, etc.), there is no such requirement for the consumers, neither have the consumers the required knowledge to assess the risks and identify the appropriate measures for their control. They simply rely on the warnings and advice on the product (or any associated literature), with no guarantee that they will actually read and fully understand.

4.10.5 Other Issues and Key Considerations in Developing a Risk Reduction Strategy

Issues that need to be taken into account when considering risks from DCM and possible risk reduction options include:

- ***the user's perception of risk***: if the user has used DCM-based paint strippers for a considerable time without a problem, he/she may consider the hazards and risks less important than they are and may be reluctant to take all necessary precautions if these could make his/her use of the product more costly, slower or more inconvenient. Moreover, as has been suggested during consultation, the availability and purchase of DCM-based paint strippers for DIY use undermines the perception of risk when using the same product in the workplace. These behavioural issues need to be taken into account when considering the way DCM-based paint strippers are currently used; and

- ***the feasibility of separating the markets for different users***: measures aimed at separating the consumer use from professional use could in theory prevent uneducated and ill-equipped consumers from unacceptable risks. However, these measures may not always be effective. As shown by journalistic research in Germany (where the sale of DCM-based paint strippers to the consumer is controlled), retailers may illegally sell these products to consumers (see the EASCR Internet site, www.eascr.org/paintstrippingontv.html). Evidently, this is a case of enforcing the law; and such issues of practicality and enforceability need to be taken into consideration (for instance, the Dutch Competent Authority has advised that, "*in the Netherlands, there is no strict separation between the market for professional use and consumer use; this means that products meant for professional use only can easily come in hands of consumers*" (RIVM, 2006a)).

5. Alternative Substances and Techniques to DCM-based Paint Stripping

5.1 Introduction to the Assessment of Alternatives

In developing any strategy for reducing the risks relating to a given substance, it is important to consider the availability of alternatives for the applications of concern, where this includes alternative substances and techniques. Such considerations are important since any proposed restrictions may instigate a shift to such alternatives. Ideally, the use of alternatives should not result in greater or equal risks to human health and the environment.

In this regard, the replacement of DCM-based paint strippers by alternative formulations or techniques needs to take account of:

- the technical suitability of the alternative substances/techniques;
- the environmental and human health risks from the use of the alternative substances/techniques; and
- the economic and social implications arising from the use (or lack) of alternative substances/techniques.

Prior to discussing these issues in detail, a key point relating to relevance of DCM in the overall paint stripping process must be borne in mind.

DCM-based paint strippers have found widespread use over several decades with very good paint stripping performance; hence, DCM may be considered to be the 'benchmark' against which other paint stripping formulations and techniques are compared. Many alternative formulations and/or techniques have resulted from concerns relating to DCM and, in fact, many have been developed by those who have manufactured DCM-based paint strippers in the past. Notably, there is a clear difference of (technical and practical) opinion between the manufacturers of DCM-based paint strippers and the manufacturers of alternatives which gives rise to a variety of claims and counter-claims which was not be possible to resolve within the agreed scope, timeframe and budget resources for this study. The following sub-Sections will thus focus on presenting the information obtained from a literature review (on the various alternative substances and techniques) and from various stakeholders.

Regardless of use category (whether consumer, professional or industrial), there are three basic methods of paint stripping (JAIC, 1993; US EPA, 1996):

- *physical/mechanical stripping* which involves the use of impaction/abrasion techniques (e.g. scraping, sanding, blasting, etc.);

- *pyrolytic/thermal stripping* which involves the use of heat/thermodynamic methods (e.g. burn-off ovens, hot fluidised beds, etc.); and

- *chemical stripping* which involves the use of chemical solvents and corrosives in varying concentrations.

These methods are discussed in detail below.

5.2 Physical/Mechanical Stripping

5.2.1 Introduction

A number of physical/mechanical stripping techniques have been identified in the literature and through consultation with industry and competent authorities across the EU. These include: abrasive blasting with a variety of media (e.g. sand, plastic, wheat, water at variable pressure, sodium bicarbonate, carbon dioxide, liquid nitrogen, etc.), use of primers before re-coating, sanding, scraping, milling with machines, etc.

Of these stripping methods, abrasive blasting is the most widely used. It involves the use of mechanical energy to hurl particles at high speed in order to remove paints and other organic coatings from metallic and non-metallic surfaces.

In discussing the various physical methods which can be used as alternatives to DCM-based stripping, it should be borne in mind that choosing the appropriate stripping method requires a consideration of many factors such as the location, size and composition of the object to be stripped, the substrate, the nature of the coating, operating costs, environmental impact, and worker safety. In particular, the size and location of the object may restrict the type of technique that can be used and the composition of the object to be stripped may limit the kinds of the stripping techniques that can be applied.

The different physical stripping methods discussed further below, therefore, focus mainly on the advantages and disadvantages (or the determining and limiting factors) associated with each stripping technique.

5.2.2 Plastic Media Blasting

Plastic media blasting (PMB) refers to a blasting process which uses soft, angular plastic particles[24] as the blasting medium. It involves propelling the plastic media at a workpiece surface using a stream of compressed air from a hose-and-nozzle system (usually in manual operations) or centrifugally from rotating wheels (in automated operations). After the coating has been removed, the workpiece is vacuumed or subjected to high-pressure air blasting to remove residual plastic dust. The plastic media are collected and cleaned and may be used several times before being discarded eventually (US EPA, 1996; NEWMOA, 2006).

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[24] Plastic media are manufactured in a variety of types, sizes and hardness; the choices of media hardness, particle size, composition, nozzle shape, angle of attack and air pressure are dictated by the coating type.

A main advantage of PMB is that it is capable of removing a coating without damaging the substrate of a delicate workpiece as well as removing individual layers of coatings. The plastic media are blasted at a much lower pressure (15 to 45 psi) than conventional blasting and, as such, is well suited for stripping paints, as the low pressure and relatively soft plastic medium have a minimal effect on the surfaces beneath the paint. It is thus used in aircraft re-painting because of the size of the product, as well as the effects of chemical strippers on non-metallic substrates and on the environment. In addition to metal finishes, PMB can be used on plastic surfaces, in particular, resistant finishes as polyurethane and epoxy coatings (US EPA, 1996; NEWMOA, 2006).

Airborne dust is, however, a safety and health concern with PMB (and most blasting operations) and operators must wear suitable PPE during stripping. A vacuum sanding system, which is essentially a dry-abrasive blasting process with a vacuum system attached to the blast head that collects the blast media and the removed coating material, can be used as an alternative to PMB (NEWMOA, 2006).

5.2.3 Wheat Starch Blasting

Wheat starch blasting (WSB) is a blasting process that generally employs the same techniques and process equipment as PMB, however, wheat starch is the blasting medium. It is softer and gentler than plastic media and, as such, is recommended for more sensitive substrates such as thin aluminium (e.g. in the aircraft industry), very soft alloys, anodised surfaces, sensitive composites, fibreglass and certain plastics (e.g. in the automotive industry). WSB can remove a variety of coatings ranging from resilient rain erosion-resistant coatings to the tougher polyurethane and epoxy paint systems and can be used on metal and composite surfaces. Direct contact of wheat starch with water must, however, be avoided to maintain the integrity of the blast media. Wheat starch is a renewable agricultural resource and hence, the spent media is biodegradable. It can also be recycled several times before the particles become too small to be effective (US EPA, 1996; NEWMOA, 2006).

5.2.4 Sodium Bicarbonate Blasting

Sodium bicarbonate blasting is similar to WSB; the key difference is that the media used for this method (baking soda) scours the surface, rather than breaking up the coating by impaction. This process usually involves a compressed air delivery system that transfers the sodium bicarbonate from a pressure pot to a nozzle (at low pressure) where the sodium bicarbonate mixes with a stream of water. The soda/water mixture impacts the coated surface and removes old coatings from the substrate; the water acts as a dust suppressant, dissipates the heat generated by the abrasive process and assists in paint removal through hydraulic action (US EPA, 1996; NEWMOA, 2006).

The effectiveness of sodium bicarbonate stripping depends on optimising a number of operating parameters such as nozzle pressure, stand-off distance, angle of impingement, flow rate, water pressure, and traverse speed. In general, sodium bicarbonate stripping systems remove paint more slowly than chemical stripping (NEWMOA, 2006).

As with WSB, this method is sufficiently gentle to remove coatings without damaging the substrate. It has thus been used to remove both friable and elastomer organic coatings on sensitive workpieces, such as thin metal parts and machinery and is also effective on metal, plastics, and wood. It may, however, have long-term corrosive effects because alkaline compounds that remain on the metal can enhance corrosion or interfere with the paint bonding. The blast media cannot be recycled, however, it can be dissolved leaving the coating debris to be filtered out for disposal (NEWMOA, 2006).

5.2.5 Water Blasting (High- and Medium-Pressure)

Water blasting is a well-established method for high-throughput surface cleaning which can be used for paint stripping of surfaces. It involves subjecting the surface to be stripped to jets of water delivered at sufficient pressure using specially designed nozzles without the benefit of an abrasive media. For high-pressure blasting operations, water is pumped at a rate ranging from 15,000 to 30,000 psi while for medium-pressure blasting; the pressure range is from 3,000 to 15,000 psi. By changing the parameters of water pressure, angle of attack, nozzle design and dwell time, reportedly, even the most durable coatings can be removed. The performance of medium-pressure systems may also be improved by applying suitable chemicals to painted surfaces prior to water blasting (US EPA, 1996; NEWMOA, 2006).

This blasting approach generally avoids the air quality issues associated with PMB and WSB and the water used in blasting operations can be recycled after if has been processed to remove debris. In the automotive industry, medium-pressure water blasting is used for stripping overspray coatings from part support hooks used in water wall spray paint booths. High (and ultra high) pressure water blasting has also been used selectively to remove resistant coatings in the automotive, aircraft, ship building, and nuclear industries (US EPA, 1996; NEWMOA, 2006).

5.2.6 Carbon Dioxide Blasting

Carbon dioxide (CO_2) blasting is a process based on the use of an inert blasting media which dissipates CO_2. There are two basic types of CO_2 blasting systems: pellet blasting for heavy cleaning and snow blasting for precision cleaning. The approach involves projecting dry ice pellets at a workpiece surface (at speeds ranging from 20 to 300 m/sec) from a nozzle. The media remove coatings by a combination of impact, embrittlement, thermal contraction, and gas expansion. The impingement of the ice crystals fractures the coating film which is then lifted off the substrate. After the pellets strike the workpiece surface, they revert to a gaseous state, both enhancing coating removal and avoiding significant residue build-up. After blasting, workpieces are subjected to jets of air to remove coating fragments (US EPA, 1996; NEWMOA, 2006).

CO_2 pellet blasting is effective in removing some paints and is excellent for components with tight tolerances. Because the approach can strip coatings selectively (i.e. specific areas of a workpiece as well as individual coating layers), it has broad application for industries processing sophisticated parts and components. Applications include the aerospace, automotive, electronics, and food processing industries. For example, this method can be used on surfaces near moving parts and on sensitive electronic pieces (US EPA, 1996; NEWMOA, 2006).

5.2.7 Liquid Nitrogen (Cryogenic) Blasting

Liquid nitrogen blasting involves cooling the workpiece before impacting it with a plastic medium. The work piece is sprayed with (or immersed in) liquid nitrogen and the coating cooled to about -195°C. Owing to the differences between the coefficients of linear expansion of organic coatings and metallic substrates, the coating cracks and delaminates as it cools. The loosened coating film is removed mechanically and the liquid nitrogen warms to ambient temperatures and evaporates into a gaseous form (US EPA, 1996).

In general, this blasting approach is used primarily to remove coating build-up from certain types of process equipment used in paints and coatings operations (e.g. paint hangers, coating racks, floor gratings) and in operations in the automotive and appliance industries. While it removes thick coatings more efficiently than thin coatings, it may also damage or distort parts because of the extreme temperatures needed in the process. Cryogenic stripping also has a harder time removing epoxy and urethane coatings than other coatings and there may be part size limitations (US EPA, 1996; NEWMOA, 2006).

5.2.8 Use of Primers

An Irish supplier of DCM-based paint strippers to the consumer (DIY) market has suggested that primer products are available, which can be painted onto old gloss/varnished surface prior to the application of a new coat of gloss/varnish. However, such products are not as popular with consumers compared with DCM-based paint strippers because such products are more expensive and are not marketed as intensively as DCM-based products. For these reasons, consumers (in Ireland) are thought to be less inclined to choose this primer alternative when stripping paint (Irish Health and Safety Authority, 2006a).

5.2.9 Sanding, Stripping Planes and Scraping

These are paint stripping techniques that may be used by consumers. Sanding essentially involves the use of sandpaper on the coated surface and may be used in combination with other methods (for instance, after a coating has been (partly) removed by the use of a hot air gun). Evidently, any damage to the substrate will depend on the experience and the skills of the operator. With paint-stripping planes, the plane is pushed with both hands over the painted surface. Rotating knives remove layers of the paint, depending on the cutting depth set (Test, 2005). In scraping, the varnish is removed by hand with sharp, differently curved blades (Test, 2005).

5.3 Pyrolytic/Thermal Stripping Methods

5.3.1 Hot Air Guns and Gas Torches

These two methods are also at the disposal of consumers for the removal of paints at home. An electric hot air gun looks like a hand-held hairdryer with a heavy-duty metal case. It has an electrical resistance coil that typically heats between 260 and 400°C. There are some heat guns that operate at higher temperatures but they should not be purchased by consumers for removing old paint because of the danger of lead paint vapours. The temperature is controlled by a vent on the side of the heat gun. When the vent is closed, the heat increases. A fan forces a stream of hot air against the painted woodwork, causing a blister to form. At that point, the softened paint can be peeled back with a scraper (putty knife). It can be used to best advantage when, for instance, a panelled door was originally varnished, then painted a number of times. In this case, the paint will come off quite easily, often leaving an almost pristine varnished surface behind. The heat gun works best on a heavy paint build-up. It is, however, not very successful on only one or two layers of paint or on surfaces that have only been varnished. The varnish simply becomes sticky and the wood scorches. The heat gun may be particularly effective for removing paint from detail work because the nozzle can be directed at curved and intricate surfaces (Weeks & Look, 2006).

Blow torches, such as hand-held propane or butane torches, were widely used in the past for paint removal because other thermal devices were not available. With this technique, the flame is directed toward the paint until it begins to bubble and loosen from the surface. Then the paint is scraped off with a scraper (putty knife). Although this is a relatively fast process, at temperatures between 1,760 and 2,100°C, the open flame can cause burns to the operator and can easily scorch or ignite the wood. Lead-based paints will vaporise at high temperatures, releasing toxic fumes that can be unknowingly inhaled. The hot air gun is generally safer to use in this respect (Weeks & Look, 2006).

5.3.2 Pyrolytic Stripping

Pyrolytic stripping equipment includes open flames, high-temperature ovens, fluidised beds and molten salt baths. At operating temperatures of up to 425°C, most organic coatings are decomposed by heat in a relatively short time. The major advantage of pyrolytic stripping is the fast and complete stripping (of resistant or accumulated coatings, in particular) while high energy use and damage to some substrates represent important drawbacks.

Coating burn-off can be achieved using a number of methods, each of which requires subjecting workpieces to extremely high temperatures. In direct burn off, workpieces are passed through either a *high-temperature-oven stripper* or a *hot fluidised-bed stripper* bed in which high-temperature flue gas (540 to 650°C) ignites the coating. Workpieces then might be subjected to an afterburner step before undergoing a step for removing inorganic residues. This approach requires the use of an after-burner to oxidise the intermediate organic products. In general, *open-flame strippers* are used on a limited basis because of environmental and safety considerations (US EPA, 1996; CMC, 2007).

Molten-salt-bath strippers use baths of proprietary molten, oxidising, inorganic salts heated to temperatures of 315 to 540°C. Coated objects are immersed in the bath for five to twenty-five minutes, depending on the salt formulation and the coating composition. This method is used for fast removal of heavy coatings deposits from process equipment.

Laser stripping is a high-tech method that uses the energy of a laser beam to decompose organic coatings. The beam is moved automatically along the substrate, decomposing the coating as it goes. This procedure is slow and works best on flat substrates (CMC, 2007).

5.3.3 Cost, Health and Safety Considerations Associated with Physical and Thermal Stripping Methods

Table 5.1 overleaf (reproduced from Test, 2005) below provides a summary comparison of some key physical methods of stripping with chemical stripping while Table 5.2 following provides indicative costs of some of the abrasive techniques.

In general, there is great variability in consultees' views on the suitability of the above physical/mechanical and pyrolytic stripping techniques. Issues that have been raised include:

- the potentially high cost of the equipment (even for the less 'sophisticated' types such as sanders- see also Table 5.2);
- the need for special equipment/tools which will be very difficult to operate for consumers and many users involved in professional uses;
- the hazards associated with the inhalation of dust resulting from the removal of paint by mechanical means (often the composition of the paint being removed is not known with possible exposure to hazardous dust, e.g. lead paint or silica dust);
- the burn (for the operator) and fire hazards from the use of thermal techniques and the noise levels during blasting;
- the risk of anoxia when using CO_2 blasting in confined or poorly ventilated surroundings as well as the (musculo-skeletal) risks to the upper limbs from using high pressure tools; and
- the risk of mechanical damage to the substrate (especially during blasting or burning) – where texture preservation is required or for small interior works, mechanical methods may be unsuitable.

Table 5.1: Summary Comparison of Physical Stripping Methods with Chemical Stripping (on wood surfaces)

	Paint Stripper	Hot-Air Gun	Paint-Stripping Plane	Sand Paper	Paint Scraper
Method	Solvent-containing or alkaline strippers soften the varnish. The sludge can be removed with a spatula or wire brush.	The paint is softened with a hot air flow of up to 650 degrees and can then be removed with a spatula.	The plane is pushed with both hands over the painted surface. Rotating knives remove layers of the paint, depending on the cutting depth set.	The varnish is removed with sand paper either by hand or using a machine (bevel, triangular or oscillating grinder).	The varnish is removed by hand with sharp, differently curved blades.
Advantages	• Suitable for carvings and carved wood with many edges and curves. • Easy to handle by consumers when the safety measures are observed.	• Suitable for all types of paint. • Suitable for carved wood with edges and curves. • Equipment also suitable for other operations, e.g. soldering or welding plastic.	• Suitable for all types of paint. • No harmful chemicals are used. • Particularly efficient with many layers of paint. • Quicker than paint strippers or hot air.	• Suitable for all types of paint. • No harmful chemicals are used. • Carved wood with edges and curves can be treated manually.	• Possible for all types of paint. • No harmful chemicals are used. • Not harmful to health because no problematic gases and dust are produced during stripping.
Disadvantages	• Some strippers contain substances harmful to health • Alkaline substances are unsuitable for acrylic paints. • In some cases, long penetration times. • Alkaline substances can discolour wood with high tannic acid contents (e.g. oak). • Lyes attack glass.	• Gas/vapour harmful to health can be produced during heating (respirator: Combined gas-particle filter A1-P2). • Acrylic paint: less suitable. • There is the danger of carbonising wood. • Glass (window) breaks readily because of the heat. • Equipment relatively noisy.	• Much dust which is harmful to health is produced (respirator required). • Only useful for flat surfaces. • In the case of unevenness and when removing the lowest layer, the wood surface can be damaged. • Very noisy (ear protection required).	• Much dust which is harmful to health is produced (respirator required). • Machines are only suitable for flat surfaces. • Tedious work, it can take a long time. • Sand paper clogs up. • Machines are very noisy (ear protection required).	• Tedious work, it takes a long time. • Less suitable for carved wood with many curves. • When removing the bottom layer of varnish, the wooden surface can be damaged. • Blades become blunt relatively quickly.
Comments	Effective strippers often contain problematic solvents although not all are dangerous. Alkaline substances are less harmful to health but often less effective. Some strippers adhere poorly to vertical surfaces others are difficult to mix. Select an appropriate stripper for your requirements	Paint stripping with hot air is an alternative non-chemical technique. Nevertheless, the method may be harmful because contaminants can be produced on heating the paint. Therefore, always wear a respirator.	The paint-stripping plane is most efficient on flat surfaces with many layers of paint but unsuitable for sensitive surfaces. The cutting depth of the plane can set between 0 and 0.3 mm and can clean rectangular areas. Longer periods of use without cleaning the blades are possible.	Compared to the plane, sanding equipment is better value for money but it is not very efficient. By choosing fine-grained sand paper, sensitive wooden surfaces can treated more gently. However, sand paper clogs quickly and must be frequently replaced; sanding also takes much longer than planing.	The paint scraper is the best method for health and the environment. It contains no contaminants; no sanding dust, solvent vapour or other gases and no stripping sludge requiring disposal is produced. However, the work is very tedious and physically the most demanding of all the procedures.

Source: Test, 2005

Table 5.2: Costs Associated with Various Physical Stripping Techniques	
Blasting technique	**Cost considerations**
Plastic Media Blasting	PMB systems can range in cost from $7,000 for a small portable unit to $1,400,000 for a major facility for aircraft stripping. Vacuum sanding is a stand-alone system and can range in cost from $17,000 to $40,000 excluding the portable generator to operate the system.
Wheat Starch Blasting	Capital costs for WSB systems vary depending upon the application; a PMB system for a small application can be modified for a cost of approximately $10,000 while an automated, closed, dust-free system for a large application (e.g. aircraft) can cost up to $1.5 million. The operating costs for WSB systems have been estimated to be 50% less than those for chemical paint stripping.
Water Blasting	The capital costs for high- and medium-pressure water processes vary considerably depending on the process and its application. Capital costs for medium-pressure systems range from $40,000 to $70,000, and capital costs for high-pressure systems range from $850,000 to $1.5 million.
Bicarbonate blasting	Compared to PMB, bicarbonate blasting is less expensive as it does not generate large amounts of waste, damage the metal and requires lesser amounts of abrasive (less than 100 kilograms/hour of bicarbonate; PMB requires 360 kilograms).
Carbon dioxide (CO_2) blasting	The equipment for this technology includes a system for converting refrigerated liquid CO_2 into the pelletised blasting media. The advantage of no media residue (only water) is thus balanced by the requirement for elaborate equipment. The blasting unit ranges from $25,000 to $50,000 and a stand-alone pelletiser can be purchased for between $50,000 and $130,000 (the cost to make pellets from delivered liquid carbon dioxide is about $0.10 to 0.15/lb or 0.22/kg to 0.33/kg).
Source: NEWMOA, 2006 *Note: the above amounts have not been translated to Euros. In early April 2007, the exchange rate was approximately $1=€0.75. It has been assumed that the cost of these techniques in Europe would be of a similar magnitude*	

5.4 Chemical Stripping

5.4.1 Introduction to Chemical Paint Stripping

Chemical paint stripping formulations range in complexity from two-ingredient solutions to systems employing primary solvents, co-solvents, activators, thickeners, wetting agents, chelating agents, corrosion inhibitors, etc. In general, the chemical stripper acts to weaken the bond between the coating and the substrate and this may occur through a variety of mechanisms including (JAIC, 1993):

- the dissolution of the paint to form a solution with the solvent;
- the destruction of the paint film by chemical reaction with the solvent; and
- the penetration of the stripper into the paint film (either directly or through scratches, holes, or broken edges) which destroys its adhesion to the base material.

The peeled-off coating and solvent sludge is then wiped, scraped or rinsed off the substrate.

In professional and consumer (DIY) applications, most chemical paint stripping is conducted by brushing the substrate with the chemical stripper; the stripper then softens or dissolves the coatings and the resulting substrate-stripper mixture is then scraped off. Subsequently, the substrate may need to be washed off after the removal of the coating to eliminate any residue left on the surface.

In industrial settings, most paint stripping is conducted by immersing or spraying the workpiece (to be stripped) with the chemical stripper. In general, spraying is used mainly where the workpiece is too large for immersion, the workpiece has sophisticated components that could be damaged by extensive contact with the solvent or only a small number of pieces - or a specific area - need to be stripped (in which case, spraying (or even brushing) might present a more cost-effective approach - compared with immersion) (US EPA, 1996).

Chemical strippers can be classified by their operating temperature - as either hot or cold - or by their composition - as corrosives (either acidic or alkaline), solvent-based or as combinations of corrosives and solvent-based. While corrosive strippers tend to be used hot (i.e. at elevated temperatures), solvent-based strippers are generally used cold (or at near room temperature).

In general, **solvent-based strippers** act by dissolving the bond between the substrate (for instance, wood or metal) and the paint. Due to their inherent (solvent) properties, they are also able to dissolve other materials (such as glues and gloves) and in some instances, evaporate quickly (and be inhaled in the process) and/or result in skin irritation or burn (CPSC, 2007). When used at room temperature (or cold), solvent-based strippers are applied by immersion, brushing or flowing and, as such, they are generally slower acting than the hot corrosive chemicals. The most widely used solvent-based strippers are formulated with DCM, n-methyl-2-pyrrolidone (NMP) and dibasic esters (DBE).

If an ionic reaction is the primary mechanism for paint removal, the stripper is classified as **alkaline or acidic (or corrosive)**, rather than solvent-based[25].

Alkaline strippers work by producing a solution containing hydroxide ions which break down the paint/coating at pH values around 13. They are one of the oldest known types of strippers and, until recently, sodium and potassium hydroxide (caustic soda and potash) were used almost exclusively. Alkalis such as soda ash and sodium silicates are now included in formulations for improved performance.

Acidic strippers operate through chemical destruction by either oxidation or dehydration of the paint/coating at pH values of around 2. They are nearly as old as the alkaline type and, until recently, concentrated solutions of sulphuric, nitric and hydrochloric acids (or combinations) were mainly used. In general, acidic strippers are difficult to work with as they readily attack most substrates; however, mildly acidic strippers or buffered acid solutions have been used to provide greater substrate versatility. Formulations that contain sulphuric or chromic acid are, however, still in use for selective applications.

25 Combination strippers are formulated using corrosives and solvents and enjoy the benefits of both. They can remove most coatings and when used at or near room temperature and below the boiling point of the solvents, they are nearly as slow acting as the solvent strippers.

In general, corrosive strippers are aqueous solutions. Typical formulations of so-called *aqueous products* generally include water (up to 95%), an organic solvent (up to 20%), an alkali or acid (10-20%), surfactants (which are caustic, stable, surface-active agents) and a chelating agent. Solutions that include larger percentages of other compounds (including other solvents) are often called *semi-aqueous* (of which the water quantity is unknown).

In general, aqueous and semi-aqueous products are usually more environmentally friendly than solvent-based cleaning and adapt to a wide variety of cleaning needs; sludge and wastewater generated by this approach are considered relatively easier to manage because there are generally fewer toxic components. These products can also be used in both spray and immersion process lines; the particular solution selected depends on both the type of substrate to be stripped and the type of process equipment used. Caustic aqueous strippers are primarily used in immersion processes during which immersion baths are heated (often to over 100°C) to accelerate the performance of the active agents; this, however, adds to operating costs.

In general, stripping paint with aqueous products is a well-established method for use in industrial operations processing metal workpieces, particularly in the automotive and heavy equipment industries. Semi-aqueous products are thought to be particularly effective for stripping resistant aircraft and aerospace paints (especially benzyl alcohol formulations); although, their higher cost and the longer time required to achieve the desired performance are considered as drawbacks. Overall, corrosive strippers are considered to have a somewhat selective chemical action and thus tend to be used in a narrower range of applications than solvent-based formulations (such as DCM-based ones).

5.5 Information Obtained from Consultation

5.5.1 Overview of Consultation Results

Information on alternatives has been sought from all stakeholders. A total of 12 completed questionnaires were received from manufacturers (eight of which were SMEs) of DCM-free paint stripping formulations while, in the course of the study, a total of 19 companies provided information on their alternative products. Twelve of these companies of these companies are also manufacturers of DCM-based paint strippers. The total tonnage of DCM-based paint strippers in 2005 for these twelve companies is almost double the total tonnage of DCM-free paint strippers for all of them[26]. The available information confirms that there are a significant number of manufacturers that supply both DCM-based and DCM-free products; in fact, all large manufacturers of DCM-based paint strippers that we have identified and contacted have alternative products in their portfolio.

In general, the main types of alternative formulations marketed by the companies who responded to the questionnaire(s) include:

26 Note that for some companies information is available for 2006, while for the majority information is available for 2005. Also note that for three manufacturers there are no tonnage data but rather of capacity.

- NMP-based products (7 companies – some in combination with DBE);
- DBE-based products (6 companies);
- dimethyl sulphoxide (DMSO)-based products (5 companies);
- alkalis (5 companies);
- benzyl alcohol-based products (4 companies);
- 1,3-dioxolane-based products (3 companies);
- glycol and glycol ether-based products (3 companies);
- other hydrocarbon-based products (2 companies); and
- other solvent-based products (2 companies).

Table 5.3 outlines the types of alternative paint stripper formulations available on the market in different European countries. This table includes information that has been received from Competent Authorities only. The '✓' symbol is used to indicate relevant applications where no further specific information is available.

Table 5.3: Types of DCM-free Alternative Paint Stripping Formulations available on the Market in Different European Countries (data mainly from Competent Authorities)

Type of alternative	FI	FR	DE	IS	IE	IT	LV	LU	MT	SI	CH
NMP-based systems	75% 50%		✓	10-25%		✓		1-ethyl-2-pyrrolidone (2687-91-4) 10-25%		✓	✓
Caustic soda-based systems	Caustic alkalis as minor components (3-5%)	?	✓		✓				✓		✓
DBE- based systems		✓	✓		✓						✓
DMSO-based systems			✓		✓		✓				
DMF-based systems								✓			
Aliphatic or aromatic hydrocarbons-based systems								Xylene 50-75%	Toluene Xylene		
Benzyl alcohol-based systems (aqueous emulsions)	40%	✓	✓		✓						✓
Acid-based systems			Formic acid								
Other organic solvent-based systems	2-(2-buthoxyethoxy) ethanol 15%	1,3-dioxolane	✓			2-phenoxyethanol 50%		1,3-dioxolane <40%			✓
Acetone or methanol-based formulations											
Organic solvents with hydrogen peroxide systems			✓								
D-limonene-based systems					✓						

Source: Consultation
Notes: In most cases, the Competent Authorities provided information from product registers where these exist

5.5.2 European Markets for Alternative Paint Stripping Formulations

Supply Chain of Manufacturers of Alternative Paint Stripping Formulations

Table 5.4 presents the available information on the supply chain of some of the respondents. For the companies for which information is available, a significant number of suppliers support the manufacture of products (although it should be noted that the two companies that have provided information appear to manufacture more than one type of alternatives). Overall, it appears that the manufacturers tend to supply products directly to companies involved industrial uses but usually through distributors to companies involved in professional uses and, obviously, to consumers.

Table 5.4: Structure of Supply Chain for Alternative Paint Stripper Formulation Manufacturers

Location and size of company	Number of types of products produced	Suppliers	Direct clients	Distribution
BE (SME)	1		10 clients in professional uses	Sales to 50 DIY stores
FR (SME)	3			Sales to ca. 600 stores for professional uses and ca. 1,400 stores for consumers
DE (SME)	3	60 companies (including 10 companies dealing with packaging)	Sales to paint producers (for private label products sold elsewhere in Europe)	Sales to 150 wholesales for companies in professional uses Sales to wholesalers for sales to DIY market (but not a key market for the company)
DE (SME)	2		Direct sales to companies in industrial uses without using any distributors	
UK (?)	1		Direct sales to companies in professional uses (specialised products)	Sales to DIY retailers
UK (SME)	4	30 suppliers of ingredients	100 customers 90% of tonnage direct to industrial customers	10% through distributors
UK (Large)	1			Sales to DIY retailers and wholesalers (mainly to consumers but professionals may also purchase)
UK (SME)	1		Usually supply to end (industrial) user	Small number of distributors in different countries

Source: Consultation

Use and Sales of Alternative Paint Stripping Formulations

We do not have sufficient information to assess the levels of usage of alternative paint stripping formulations in Europe at present. According to data presented by CEFIC at the November 2005 Forum (CEFIC, 2005), the 2003 breakdown of the 5,231 tonnes of paint strippers sold in the United Kingdom and Ireland was:

- DCM-based: 93%;
- caustic: 4%; and
- non DCM solvent-based: 3%.

These estimates were based on data collected from the nine formulators formulating both DCM-based and alternative paint strippers, representing more than 85% of the domestic market. The same source also suggests that:

- alternatives only have a very limited market penetration - reports from various sources indicate that the market penetration is 10% or less; and

- 75% of the paint strippers sold in Germany in 2003 were based on DCM (this assertion was based on a third source – a letter from industry to DG Enterprise in 2004).

However, the data presented by CEFIC may be dated and, since 2003, the market share for alternatives may have increased. For instance, while the 7% share of alternatives in the UK would translate to around 360 tonnes[27], the combined production tonnage of UK manufacturers of alternatives that we have contacted are:

- 590 tonnes of alternatives for industrial uses;
- 1,620[28] tonnes of alternatives for professional and consumer uses; and
- 95 tonnes of alternatives for a mix of industrial/professional/consumer uses.

Among the different types of alternatives, NMP-based and DBE-based (or DBE-containing) formulations appear to have the a significant, if not the largest, market share, not least because the results of the market survey in Germany presented in Annex C show that NMP may be found in 63% of the products in the survey sample. A large UK manufacturer of paint strippers has suggested that, in the UK, "(the share of) *DCM-free* (paint strippers) *is probably less than 200 tonnes per year. These types are mainly DBE based, some still containing NMP, but other "new" solvents appearing*". The assertion of the manufacturer is in line with the expected consequences of the recent classification of

[27] Note that another presentation at the November 2005 Forum suggested that the UK market in caustic paste strippers alone amounts to about 300 tonnes per annum (Percival, 2005).

[28] This includes the capacity of a manufacturer who declined to provide exact tonnage data. Also, a considerable part of this tonnage is represented by alkalis which the manufacturer himself does not consider as being 'direct alternatives' to DCM-based formulations.

NMP as Category 2 Reprotoxic substance which is very likely to seriously impact the use of this substance in paint stripping formulations (especially for consumer use).

The assertion that the UK market share of alternatives has (significantly) increased since 2003 is consistent with information obtained from the two largest DIY retail chains in the country.

A supplier of DCM-based paint strippers to the German market has advised us that "*in industry, normally liquid products in dip tanks are used and during the last 15 years nearly all companies replaced DCM-products (working at 20°C) with DCM-free products based on high boiling solvents or caustic soda (all working at 80-90°C). In Germany, the DCM-based products for dip tanks have been replaced by other products due to the 2.BImSchV regulations…In our technical data sheet of DCM-products, we recommend to users to substitute them by DCM-free-types*".

Further to the responses collected through consultation in the form of questionnaires, France and the United Kingdom account for the majority of sales of alternative paint strippers by the respondents. Other countries with noticeable consumption of alternative paint stripping formulations are Spain, Belgium and Germany. It should not be assumed, however, that the sales of the respondents are necessarily representative of the sales of alternative paint strippers in the whole of the EU+EEA+Switzerland.

Applications of Alternative Paint Stripper Formulations

The use categories supplied by the alternatives manufacturers responding to the RPA questionnaire are as follows:

<u>Industry uses (7 responses)</u>

- Paint removal from metal surfaces by either application or immersion methods;
- degreasing, cleaning and maintenance;
- removal of adhesives and ink in the printing industry;
- graffiti removal; and
- removal of paint from aircraft exteriors.

<u>Professional uses (8 responses)</u>

- Paint removal from building exteriors;
- paint removal for building interiors; and
- removing plaster, anti-corrosive paint, and PCB-contaminated paint.

<u>Consumer uses (8 responses)</u>

- Furniture finish stripping;
- interior paint removal;
- graffiti removal; and
- brush cleaning.

These are largely similar, if not identical, to the applications of DCM-based paint strippers. It should be noted that these applications were identified through consultation and that this list should not be considered as being exhaustive.

Size of Containers for Alternative Paint Stripping Formulations

Information has been received on the sizes of containers available on the market and the most 'popular' sizes for the products manufactured by respondents to the RPA questionnaire. For:

- industrial uses, the smaller size is 1 kg but, generally, sizes are from 10 litres and upwards. The popularity of sizes varies considerably but in the majority of the cases, the most 'popular' sizes are 25 litres or larger;

- professional uses, 5 litres is the size most companies offer along with 20-25 litres. The most popular size appears to be 5 litres; and

- consumer uses, sizes start from 0.25 litre, although most are usually 0.5 litre or larger. 0.5 and 1 litre are almost equally popular.

5.5.3 Choice of Alternative Substances to be assessed

It is evident that there is a significant variety of formulations that may be used as alternatives to DCM-based paint stripper, although they may not necessarily be suitable for every application of DCM-based formulations. It is, therefore, important that the substances chosen for further consideration are representative of the range of alternatives. Hence, the key criteria for choosing substances to be further assessed are:

- the substances should have equivalent functionality to that of DCM, i.e. they should act as the 'active' ingredient which play the key role in removing the paint[29];
- they must be widely used;
- they must be used at sufficient percentages in the formulations; and
- they must be representative of all uses of DCM-based formulations (industrial, professional and consumer).

Taking the above into account, the following chemical substances are examined in further detail in this Section:

- n-methyl-2-pyrrolidone (CAS No. 872-50-4);
- benzyl alcohol (CAS No. 100-51-6);
- dimethyl sulphoxide (CAS No. 67-68-5);

[29] Note that alternative formulations may contain a range of substances that may have the potential to cause adverse effects on the user and/or the environment. Similarly, substances contained in DCM-based formulations may also have the potential to cause harm to the health of the user and/or the environment.

- 1,3-dioxolane (CAS No. 646-06-0);
- sodium hydroxide (CAS No. 1310-73-2); and
- dibasic esters (CAS Nos. 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2 (the last one is the CAS Number for the mixture of the three individual dibasic esters)).

The following paragraphs (or sub-sections) discuss in more detail these substances in terms of:

- identity and applications;
- technical suitability;
- human health and environmental hazards; and
- relative costs.

While human health and environmental hazards will refer to the specific substance, the other parameters will largely apply to its paint stripping formulations.

A summary of the physicochemical, toxicological and ecotoxicological profile of the main alternatives is given in Table 5.5 where DCM's properties are compared to those of the selected alternative substances. Table 5.6 that follows presents the OELs for the alternatives in a number of European countries.

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
Identification							
EINECS/EC No.	200-838-9	212-828-1	203-419-9 214-277-2 211-020-6	202-859-9	200-664-3	211-463-5	215-185-5
CAS No.	75-09-2	872-50-4	106-65-0 1119-40-0 627-93-0	100-51-6	67-68-5	646-06-0	1310-73-2
Formula	CH_2Cl_2	C_5H_9NO	$C_6H_{10}O_4$ $C_7H_{12}O_4$ $C_8H_{14}O_4$	C_7H_8O	C_2H_6OS	$C_3H_6O_2$	NaOH
Vapour pressure	475 hPa at 20°C	0.32 hPa at 20°C	0.008-0.3 hPa at 20°C	<0.1 hPa at 20°C	0.55 hPa at 20°C	93 hPa at 20°C	<10^{-5} hPa at 25 °C (calculated)
Classification	Xn: Harmful Carc Cat. 3 R40: Limited evidence of a carcinogenic effect	The agreed new classification will be: Xi: Irritant R36/37/38: Irritating to eyes, respiratory system and skin R61: Repr. Cat. 2 NMP will not be in Annex I of Directive 67/548/EEC as the 30th and 31st ATP will be not published as such but included in the GHS	Not classified in Annex 1 of Directive 67/548/EEC	Xn: Harmful R20/22: Harmful by inhalation and if swallowed.	Not classified in Annex 1 of Directive 67/548/EEC	F: Flammable R11: Highly Flammable	C: Corrosive R35: Causes severe burns

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
Labelling	S2: Keep out of the reach of children S23: Do not breathe gas/fumes/vapour/spray (appropriate wording to be specified by the manufacturer) S24/25: Avoid contact with skin and eyes S36/37: Wear suitable protective clothing and gloves	S2: Keep out of the reach of children S41: In case of fire and/or explosion do not breathe fumes	No labelling	S2: Keep out of the reach of children S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice	No labelling	S2: Keep out of the reach of children S16: Keep away from sources of ignition – No smoking	S1/2: Keep locked up and out of the reach of children S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice S37/39: Wear suitable gloves and eye/face protection. S45: In case of accident or if you feel unwell, seek medical advice immediately
Danger symbols	Xn: Harmful	Xi: Irritant	-	Xn: Harmful	-	F: Flammable	C: Corrosive
Ambient State	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Solid
Health Endpoints							
Acute oral toxicity (LD_{50})	1,410 - 2,524 mg/kg (rat) (TNO, 1999) 1,600 mg/kg bw (rat)	3,600 - 4,200 mg/kg bw (rat) (industry has suggested a higher value of 8,000 mg/kg bw)	>5,000 mg/kg bw (rat) 1,920 mg/kg bw (rat) 8,191 mg/kg bw (rat)	1,230 mg/kg bw (rat)	17,100-26,900 mg/kg bw (mouse); 13,400-28,300 mg/kg bw (rat)	5,200 mg/kg (rat)	LD_{50} 325 mg/kg bw (rabbit)
Acute inhalation toxicity (LC_{50})	49,000– 78,000 mg/m^3 (mouse and rat)	5.1 mg/l (rat)	> 4.1 mg/l (4 h) Inhalation may cause reversible blurring of vision	>4.2 mg/l (4-h) (rat)	LC_0: >1,600 mg/l (4-h) (rat) - 2000 mg/l (40-h) (rat);	68.4 mg/l (4-h) (rat)	No data available
Acute dermal toxicity (LD_{50})	>2,000 mg/kg bw (rat)	7,000 mg/kg bw (rat) 2,000 – 4,000 mg/kg bw (rabbit)	>5,000 mg/kg bw (rabbit) > 3,400 mg/kg (rabbit)	2,000 mg/kg bw (rabbit)	LD_0 ca. 40,000 mg/kg bw (rat)	15,100 mg/kg bw (rabbit)	1,350 mg/kg bw (rabbit)

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
Skin Irritation	Irritating (rabbit)	Slightly irritating (rabbit) Irritating (human)	CAS No: 106-65-0 → Not irritating CAS No: 1119-40-0 → Highly irritating (rabbit) CAS No 627-93-0 → No data	Not irritating (rabbit)	Slightly irritating (guinea pig)	Irritating	Irritating and corrosive
Eye Irritation	Slightly irritating (rabbit)	Irritating (rabbit)	CAS No: 106-65-0 → Irritating (rabbit) CAS No: 1119-40-0 → Slightly irritating CAS No 627-93-0 → No data	Irritating (rabbit)	Slightly irritating (rabbit)		Irritating and corrosive (rabbit)
Skin Sensitisation	Not sensitising (human)	Not sensitising (guinea pig, human)	CAS No: 106-65-0 → No data CAS No: 1119-40-0 → Not sensitising CAS No 627-93-0 → No data	Sensitising	Not sensitising (guinea pig, human)		Not sensitising
Repeated Dose Toxicity	Oral: liver/kidney damage reported	Oral: Mice NOAEL: 2,500 ppm in males and 7500 ppm in females, based on the kidney histopathology Oral: Mice NOAEL 1,000 ppm based on the liver responses at higher doses.		Considered to be of moderate toxicity	Oral: NOAEL 1,100 mg/kg bw (rat, 18 months); 8910 mg/kg bw (monkey, 18 months)	Oral: NOAEL for gavage were 75 mg/kg/day. Most sensitive organ system appear to be the blood-forming organs	Corrosive action on dermal, bronchial, intestinal and renal tissues observed Although two inhalation studies show local effects of the respiratory tract after repeated NaOH exposure, the

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
	Inhalation: adverse effects on CNS, cardiac injury, heart failure and death	Inhalation: irritation of upper airways observed in animal studies Rats NOAEL 500 mg/m^3.			Inhalation: NOAEC 0.964 mg/l for respiratory effects, 2,783 mg/l for systemic effects (rat, 13 wks)	Inhalation: NOAEL (14-day) 516 ppm NOAEL (13 wks) 1,000 ppm	data are not adequate to establish an N(L)OAEL because the exposure concentrations were not specified
Mutagenicity (Genetic Toxicity)	*in vitro*: mammalian cell: negative; Ames test: positive	*in vitro*: negative	*in vitro*: negative	*in vitro*: negative	*in vitro*: negative	*in vitro*: negative	*in vitro*: the effect of sodium hydroxide is of a methodical kind and not valid to asses the genotoxicity under realistic conditions.
	in vivo: inconclusive	*in vivo*: negative	*in vivo*: negative	*in vivo*: inconclusive	*in vivo*: wide array of genetic toxicity tests are generally negative, although one study showed evidence of chromatid breaks in rats.	*in vivo*: negative (positive results from low reliability studies)	*in vivo*: negative
Carcinogenicity	Classified as category 3 carcinogen	Has been reported to have no oncogenic potential.	None reported	None reported	None reported	No known completed and reported studies	Systemic carcinogenicity is not expected to occur because NaOH is not expected to be systemically available in the body under normal handling and use conditions. No suitable studies are available to assess the risk on local carcinogenic effects.

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
Reproductive Toxicity	No reprotoxic effects reported	By oral route in rat, there was evidence of reproductive toxicity at least at the highest dose (male and female fertility was affected). Those effects went with histological changes in both sexes. The Commission Working Group on C & L of Dangerous Substances decided at its meeting in November 2003 that NMP should be reclassified as T, Repr. Cat 2.	No reprotoxic effects reported	No data available	No reprotoxic effects reported	Reprotoxic effects have been reported in a One Generation Reproduction Study (drinking water, high dose) and a One Generation Reproduction Study (drinking water, low dose) (both rat)	No data available

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide
Environmental Endpoints							
Persistence and Degradation	Not expected to persist	Not persistent	Not persistent	Not persistent	Not persistent		Rapidly dissolves and dissociates in water. Not persistent
	Not readily biodegradable 5-26% after 28 days	Readily biodegradable 73 % after 28 days	Readily biodegradable 98% after 28 days	Readily biodegradable 95% after 28 days	92.5% after 32 days Has a good potential for biodegradation but it is recommended to be careful about its concentration in effluent because toxic effects can appear	Not readily biodegradable	Not relevant
Bioconcentration	Not expected to bioaccumulate	Not expected to bioaccumulate	No data available	Not expected to bioaccumulate	Not expected to bioaccumulate	Not expected to bioaccumulate	Not relevant
Ecotoxicity	Fish: 96h-LC_{50} = 193 mg/l	Fish: 96h-LC_{50} = 832mg/l (bluegill)	Fish: 96h-LC_{50} = 18 – 24 mg/l	Fish: 96h-LC_{50} = 10mg/l	Fish: 96h-LC_{50} 33,000-37,000 mg/l	Fish: 96h-LC_{50} = 95.4 mg/l	Fish: LC_{50} = 33 - 160 mg/l
	Daphnia: 48h-EC_{50} = 135 – 220 mg/l	Daphnia: 24h-EC_{50} > 1,000 mg/l; 48h-EC_{50} > 500 mg/l	Daphnia: 48h-EC_{50} = 112 – 150 mg/l	Daphnia: 24h-EC_{50} = 400 mg/l	Daphnia: 24h-EC_{50} = 7,000 mg/l;	Daphnia: 48h-EC_{50} >772 mg/l	Daphnia: 48h-EC_{50} = 40 mg/l
	Algae: 96h-IC_{50} > 660 mg/l	Algae: 72h-EC_{50} > 500mg/l	CAS No: 106-65-0 → 96h-IC_{50} = 11.9 mg/l CAS No: 1119-40-0 → 96h-IC_{50} = 7.2 mg/l CAS No 627-93-0 → 96h-IC_{50} = 4.4 mg/l	Algae: 3h-EC_{50} = 35mg/l	Algae: 96h-EC_{50} = 12,350-25,500 mg/l	Algae: 72h-EC_{50} >877mg/l	Algae: no data available. Algae destroyed at pH > 8.5

Table 5.5: Comparison of Alternative Substances to DCM in Chemical-based Paint Strippers

EINECS Name	DCM	N-methyl-2-pyrrolidone	Dibasic Esters	Benzyl Alcohol	Dimethylsulphoxide	1,3-Dioxolane	Sodium Hydroxide

<u>Sources:</u>
All substances: ECB European Chemical Substances Information System (ESIS) website – www.ecb.jrc.it/esis
All Substances (except 1,3-dioxolane): IUCLID data sheet dated 19 February 2000
DCM: TNO (1999), Manufacturers Safety Data Sheet and Euro Chlor (1999)
NMP: SCOEL (2006)
Dibasic Esters: Additional information from manufacturer of DBEs and SOCMA (2002)
DMSO: Also used IUCLID Datasheet of 2004 by Atofina submitted to the US EPA under the US EPA HPV Programme, also data from TRGS 612
1,3-Dioxolane: USEPA HPV Challenge Program Submission by Dioxolane Manufacturers Consortium, November 2000.
Sodium Hydroxide: information has been used from the July 2006 Final Draft of the ESR Risk Assessment for the substance prepared by the Portuguese Rapporteur
We have also consulted with a number of manufacturers of these substances
LCL0 = Lowest Published Lethal Concentration

Table 5.6: Occupational Exposure Limits for DCM and the Selected Alternatives

Subs-tance	CAS Number	Occupation Exposure Limit (8 hour TWA in ppm/mgm^{-3})																			
		AT	**BE**	**BG**	**CZ**	**DE**	**DK**	**EE**	**ES**	**FI**	**FR**	**HU**	**IE**	**LU**	**NL**	**NO**	**PL**	**SE**	**SK**	**UK**	**CH**
NMP	872-50-4	20/80				19/80	5/20	50/200	25/103	25/-			25/101		20/80	5/20	-/120	50/200		25/103	20/80
BA	100-51-6			-/5	-/40																-
DMSO	67-68-5	50/160						50/150							-/150			50/150			50/160
1,3-DO	646-06-0						-/100[30]					-/10	20/-				-/10				-
NaOH	1310-73-2	-/2	-/2	-/2	-/1		-/2					-/2				-/2	0.5/1	-/1	-/2		-/2
DBE (DMS)	106-65-0																	1/30			-
DBE (DMG)	1119-40-0																	5/33			-
DBE (DMA)	627-93-0																	5/36			
DCM	75-09-2	50/175	50/104	-/100	-/200		35/122	35/120	50/177		50/180	-/10	50/174		100/ 350	15/50	-/20	35/120	100/ 350	100/ 350	50/-

Notes:
BA: benzyl alcohol
1,3-DO: 1,3-dioxolane
DMS: dimethycl succinate
DMG: dimethyl gluratate
DMA: dimethyl adipate
In grey background are the OELs which are lower than the respective OEL for DCM in the country in question

30 Tentative limit value

5.6 N-Methyl-2-Pyrrolidone (NMP)

5.6.1 Identity

The typical pH of NMP is 8.0 to 9.5. It is a highly polar colourless liquid with a mild amine odour. NMP is a very stable, water-soluble cleaner, with a high flashpoint (91 °C) and low vapour pressure (0.32 hPa at 20°C). It is biodegradable with a minimal potential for bioaccumulation (US Navy, 2003a).

Its applications include electronics, graffiti removers, agricultural formulations (herbicide, pesticide, and fungicide formulations), pharmaceuticals, consumer and industrial cleaners, coatings solvent and petrochemical processing (Lyondell, 2004a).

5.6.2 Technical Characteristics

According to an NMP manufacturer, NMP and NMP-based formulations are "*the leading methylene chloride substitutes for paint stripping, graffiti removal, and industrial cleanup*". NMP's advantages over DCM are claimed to include (Lyondell, 2006):

- low odour;
- low evaporation rate (which prevents re-adhesion of paints);
- non-carcinogenic; and
- completely water soluble and rinseable.

Depending on the application, the manufacturer recommends either straight NMP or a blend of NMP and a co-solvent or co-solvents. Straight NMP is recommended for applications where high performance is critical or users require recovery and recycling of the NMP. Used NMP can be recycled in-house using commercial vacuum distillation equipment or sent to a recycler for recovery (Lyondell, 2006).

NMP removes paint more slowly than DCM, but NMP dissolves multiple layers rather than lifting each coat (US Navy, 2003a). NMP-based formulas will effectively strip acrylic latex gloss, epoxy spray paint, polyurethane gloss enamel, high gloss polyurethanes and tallow oil alkyd spray paints (US Navy, 2003a).

Adding a small amount of non-ionic surfactant to the straight NMP is recommended to improve wetting and reduce stripping time. For immersion stripping of small painted parts, heating NMP to 63°C can reduce stripping times (Lyondell, 2006).

For consumer and industrial applications where the NMP is not recovered or high performance is not required, NMP can be blended with co-solvents to reduce cost and be further modified with surfactant and thickeners (Lyondell, 2006). Hydrocarbons such as aromatics or mineral spirits can also be blended with NMP to lower cost. Xylene and toluene are effective co-solvents. The disadvantages of using hydrocarbon co-solvents include higher odour and flammability (aromatics), storage stability (mineral spirits), and water rinseability. Storage stability and water rinseability can be improved by adding surfactants and using a non-cellulosic thickener (Lyondell, 2006).

Behaviour of NMP with Different Materials and Exposure Controls

NMP dissolves polyamides, polyimides, polyesters, polystyrenes, polyacrylonitriles, polyvinyl chlorides, polyvinyl acetates, polyurethanes, polycarbonates, polysulphones, polymethylmethacrylate, and many copolymers. NMP will dissolve or swell Buna-N rubber, natural rubber, neoprene, and fluororubber (US Navy, 2003a).

NMP does not react with most metals, including steels, aluminium, nickel, silver, gold, chromium and chromates, copper, tin, and silicon. However, it should not be used with bronze or brass valves in process piping (US Navy, 2003a).

The following *Exposure Controls and Personal Protection Measures* are suggested by the manufacturer (Lyondell, 2004b):

- ***engineering controls***: at elevated temperatures, special ventilation may be required even if the flash point has not been exceeded. Flammable mists or aerosols can be generated below the flash point of high boiling liquids; and

- ***personal protection***: if exposure can potentially exceed the exposure limit(s),respiratory protection recommended or approved by appropriate local, state or international agency must be used. Users should wear chemical resistant gloves such as: butyl rubber[31]. When skin contact is possible, protective clothing including gloves, apron, sleeves, boots, head and face protection should be worn. The equipment must be cleaned thoroughly after each use. Eye protection, including both chemical splash goggles and face shield, must be worn when possibility exists for eye contact due to splashing/spraying liquid, airborne particles, or vapour.

Information from Ansell Europe, the Internet site of which has been used in the discussion of gloves presented in Section 4.9, suggests that the suitable gloves for NMP (not necessarily for NMP-based formulations) are:

- neoprene (breakthrough time: 26 minutes, Protection Index 1); and
- nitrile (breakthrough time: 20-27 minutes, Protection Index 1).

Interestingly, the US publication mentioned above (US Navy, 2003a) suggests that neoprene gloves are not suitable for protection against NMP.

A recent (US) study, however, has suggested that "*formulations containing NMP…showed less rapid permeation of butyl gloves and in many cases showed no detectable permeation for the selected butyl and natural rubber glove styles*" (Stull *et al*, 2002).

Using the Carl Roth Internet site, the costs of these gloves are €13.50 (thickness 1.0 mm) and €14.80 (thickness 0.8 mm) respectively. These are considerably lower than the cost of the gloves that appear to be appropriate for DCM; still, their Protection Index is quite

31 These could cost as much as €17, according to the Carl Roth Internet site (www.carl-roth.de).

low. These prices are for indicative purposes only; when buying in bulk or form other suppliers, costs may vary.

It should be noted that the information on the protection offered by different types of gloves is given for comparison only. Solvents may show a different permeation pattern, especially in mixtures, thus formulations with several solvents require multiple consideration or, even better, testing by the formulators. So, there is doubt whether the gloves recommended for alternative solvents would also be suitable for paint strippers based on these solvents.

Composition of NMP-based Paint Strippers

Table 5.7 outlines a selection of compositions of NMP-based paint strippers. The 'active' ingredients[32] are displayed in bold (where these are not NMP) and the last column to the right provides any available information on the applicability of the various formulations (IND: industrial uses, PROF: professional uses; CON: consumer uses). The table below is based on information collected in the course of the study; it is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.

Table 5.7: Composition of NMP-based Paint Stripping Formulations

Ingredients (and supporting components)	**CAS Number**	**Percentage in formulation**	**Relevant applications and other notes**
N-methyl-2-pyrrolidone	**872-50-4**	**Up to 75%**	IND (multimetal – aircraft tank type strippers), PROF, CON
Dimethylsulphoxide	67-69-5		
Sodium hydroxide	1310-73-2	3 %	
1,2-ethandiol (ethylene glycol) Potassium hydroxide	107-21-1 1310-58-3	20 % 5 %	
1-ethyl-2-pyrrolidone	2687-91-4		
Formic acid Sodium dodecyl benzenesulphonate	64-18-6 25155-30-0	<1% 1-5%	
Butane Ethanol Methanol Sodium di(2-ethylhexyl) sulphosuccinate Sodium hydroxide Solvent naphtha (petroleum), Light arom; low boiling point naphtha <0.1% benz. White spirit	106-97-8 64-17-5 67-56-1 577-11-7 1310-73-2 64742-95-6 64742-82-1	5-10% <1% <1% 1-5% <1% <1% 10-30%	
1,3-dioxolane Dimethoxymethane Naphtha, heavy	**646-06-0** 109-87-5 64742-82-1	**<40%** <20% 10-25%	

32 The alternatives are grouped on the basis of the active ingredient i.e. the ingredient that performs the removal of paint. If there exist two or more ingredients in the formulation that may be considered as 'active', we choose to characterise the formulation on the basis of the ingredient with the highest concentration.

Table 5.7: Composition of NMP-based Paint Stripping Formulations			
Ingredients (and supporting components)	**CAS Number**	**Percentage in formulation**	**Relevant applications and other notes**
Methyl ethyl ketone N-methyl-2-pyrrolidone D-limonene Xylene Ethylbenzene Petroleum naphtha	**78-93-3** 872-50-4 5989-27-5 1330-20-7 100-41-4 64742-48-9	**50-100%** 10-25% 0-2.5% 2.5-10% 2.5-10% 0-2.5%	Paint stripper for wood surfaces coated with acrylic/alkyd paints, varnishes or stains
Water Anisole Amyl acetate Formic acid	64-18-6		
Water Methylbenzotriazole Tetrapropylbenzene Ammonia Diethanolamine borate			
Base formulations			
N-methyl-2-pyrrolidone Propylene glycol methyl ether acetate Surfactant Hydroxypropylcellulose		40% 57% 0-2% 1%	Base formulation for CON and IND applications where the NMP is not recovered or high performance is not required
N-methyl-2-pyrrolidone Dipropylene glycol methyl ether acetate Surfactant Hydroxypropylcellulose		40% 57% 0-2% 1%	Base formulation for CON and IND applications where the NMP is not recovered or high performance is not required
N-methyl-2-pyrrolidone Dipropylene glycol methyl ether acetate t-Butyl acetate (or water) t-Butyl alcohol Surfactant Hydroxypropylcellulose		32% 32% 30% 3.5% 2% 1.5%	Base formulation for low-VOC formulations
N-methyl-2-pyrrolidone Dipropylene glycol methyl ether acetate Sodium hydroxide Surfactant Hydroxypropylcellulose		35% 59-61% 0-2% 1-2% 1-2%	Base formulation for graffiti removers
Source: Consultation *Percentages in formulation and CAS Number provided where available.* *This table is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.*			

5.6.3 Human Health and Environmental Hazards

Although NMP does not appear to be a sensitising agent, it is a severe eye irritant (US Navy, 2003a). The vapour pressure or volatility of this product at room temperature is very low, thus reducing the potential of exposure by inhalation (US Navy, 2003a).

In vitro studies indicate that NMP has a high permeability through both human and rat skin (Ursin *et al*, 1995; Priborsky & Mühlbachova 1990). Studies in workers and human volunteers have shown that NMP is readily absorbed by the inhalation, ingestion and dermal routes. NMP is extensively metabolised and only a minimal fraction of unchanged NMP is eliminated in urines (INRS, 2002).

NMP has also been recently re-classified as 'toxic to reproduction' Cat. 2 (still this has not been included into Annex 1 to Directive 67/548/EEC). Due to the new classification, the future of NMP in paint stripping formulation is currently in doubt and some manufacturers of paint stripping formulations are considering new active substances (a manufacturer of paint strippers who uses NMP noted "*if NMP becomes Reprotoxic Cat 2 (with a concentration limit of 0.5% or 5%) the preparation also becomes also Reprotoxic Cat 2 and could only be sold to the professional user. We sell at least 45% of this paint stripper in the DIY market. Conclusion: to be replaced by a NMP-free product*"; another manufacturer added: "*actually we still sell NMP-strippers but we are searching for alternatives. When NMP-strippers have to be labelled as "Toxic" we will stop sale*"). Among the potential alternatives is n-ethyl-2-pyrrolidone (NEP) which has a very similar structure (the structural similarity between chemical compounds occasionally suggests similarities in toxicological and/or ecotoxicological properties).

Exposure Information

NMP concentrations in air in the personal breathing zones of graffiti removers are reported to be up to 10 mg/m^3, both short peak exposure (Anundi *et al*, 1993) and 8-h TWA (Anundi *et al*, 2000). In the paint stripping industry, workers are exposed to NMP concentrations up to 64 mg/m^3 (personal breathing zones, 8-h TWA), and 1-h peak samples revealed concentrations up to 280 mg/m^3 (Åkesson & Jönsson, 2000).

An examination of the OELs for NMP in a number of countries (as shown in Table 5.5) shows that they are considerably lower than those for DCM, however, the lower volatility of the substance contributes to exposure concentrations generally lower than those of DCM during paint stripping operations. Therefore, the OEL allow cannot be used to assess whether a substance is more or less hazardous than DCM. In relation to this, Altnau (2004) has discussed the importance of not comparing OELs but rather Vapour Hazard Ratios for solvents; these are the ratios of saturation concentration over the OEL value for the solvent which shows by how many times a vapour saturated air volume has to be diluted by the same volume so that the OEL for the solvent is not exceeded. Due to its high volatility, DCM has a high saturation concentration and this results in a much higher Vapour Hazard Ratio compared to the alternative solvents discussed in this report. On the other hand, it should be noted that both DCM-based and some alternative products contain vapour retardants that delay to an extent the release of vapours.

5.7 Dibasic Esters

5.7.1 Identity

Dibasic esters (DBEs) are refined dimethyl esters of adipic (10-25%), glutaric (55-65%), and succinic acids (15-20%). The primary product is designated DBE. DBE is further distilled to produce six DBE fractions for specialty applications: DBE-2, DBE-3, DBE-4, DBE-5, DBE-6, and DBE-9. DBEs are clear, colourless liquids having a mild, fruity odour. They are readily soluble in alcohols, ketones, ethers, and many hydrocarbons, but are only slightly soluble in water and higher paraffins (Invista, 2006a). DBEs are non-flammable and readily biodegradable (Invista, 2006b).

Applications of DBEs include solvents (in industrial coatings, coil/sheet coatings, paint removers, etc.), plasticisers, polymer intermediates and specialty chemical intermediates (Invista, 2006a).

5.7.2 Technical Characteristics

According to a manufacturer of DBEs, DBEs offer the following advantages (Altnau, 2004):

- high solvency power;
- high boiling point;
- slow evaporation;
- high flash-point;
- low miscibility with water (favourable for waste water treatment);
- high miscibility with most organic solvents;
- not classified in Europe;
- very low emission rate;
- not classified as VOC in Europe;
- not classified as a solvent according to Directive 1999/13/EC;
- readily biodegradable; and
- recyclable by vacuum distillation

Performance of DBE-based Paint Strippers

DBE may be used at 100% strength or mixed with other chemicals (for instance, a manufacturer of DBEs suggests that a 100% DBE formulation may be used hot for dip stripping). However, discussions we have held with industry consultees suggest that DBE on their own generally do not have an acceptable stripping performance when used on their own. Notably, the results of testing presented in Section 5.13.2 shows that the product based on DBE alone was generally ineffective (under the conditions of the test which did not involve dip stripping).

According to an EU manufacturer of DBEs, DBE has been demonstrated as an effective consumer paint stripper for stripping paints from wood, metal and other surfaces, as well as being used as an effective industrial hand cleaner. DBEs are also being used in formulations for cleaning paint spray booths, paint circulating systems, robots, spray guns and nozzles. These strippers can be formulated with a thickener, activator, or other additives and are easily prepared (Invista, 2006b).

The DBE-based strippers presented in technical information issued by the manufacturer of DBEs generally require removal times up to twice that of DCM-based strippers depending on the coating (20-30 min vs. 15 min). The manufacturer argues that this is an advantage because DBE-based strippers offer highly flexible work times of more than 24 hours (Invista, 2006b).

The manufacturer notes that DBE-based strippers are effective on a wide range of paints. On some coatings that are more difficult to strip, such as epoxies, more than one treatment with DBE-based strippers may be necessary. DBE-based strippers perform somewhat differently from DCM-based paint strippers. While DCM-based strippers show bubbling, crinkling, and lifting, DBE softens paint to a paste-like consistency. This paste can be removed with a putty knife. The softening action is claimed to also minimise damage to wood substrates compared to DCM and often results in more complete removal of the coating. It is of note that the manufacturer of DBEs claims that DBE-based strippers are used for restoration of valuable antiques because they do not raise the wood grain, as do some DCM-based formulations (Invista, 2006b). However, there is no other source making this claim. In fact, one of the reasons users who are involved in restoration and conservation work may show a preference towards DCM-based paint strippers is that it does not raise the wood grain (as opposed to caustic products, for instance). Therefore, DBE-based products are likely to offer no advantage in comparison to DCM-based paint strippers.

Removal of alkyd exterior enamel, marine paints and marine varnish is fair. Military specified aircraft coating of polyurethane over epoxy primer is resistant to attack and may require multiple applications of stripper or use of activators. The suggested base formulations (presented in Table 5.8) should be used as starting points and may need to be customised for specific applications (Invista, 2006b).

DBE microemulsion (DBE-ME) is an effective aqueous-based paint stripper offering the advantages of (Invista, 2006b):

- performance with less VOC content;
- complete water rinsibility; and
- low flammability.

According to the manufacturer of DBEs, DBE-ME, is effective in removing a wide range of paints and has been shown in the lab to be as effective as neat DBE on some paint types. Even tough coatings, such as epoxies and marine paints, were removed with DBE-ME. Co-solvent addition allows the formulation to be tailored for optimum removal of specific paints (Invista, 2006b). We have also identified a microemulsion product that contains DBEs; this is a water-based product manufactured by a UK formulator. This product does not follow the DBE-ME base formulation of the DBE manufacturer mentioned above and should not be confused with what is described in Invista (2006b).

Finally, it is also claimed that DBE formulations are effective at removing graffiti from walls and buildings including the removal of ink and felt-tip markers, acrylic spray paint and crayons on porous surfaces such as brick and on hard surfaces such as railcars (Invista, 2006b).

Composition of DBE-based Paint Strippers

Table 5.8 outlines a selection of compositions of DBE-based paint strippers (with the percentage in formulation and CAS Numbers provided where available). The 'active' ingredients[33] are displayed in bold and the last column to the right provides any available information on the applicability of the various formulations (IND: industrial uses, PROF: professional uses; CON: consumer uses). The table below is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.

Table 5.8: Composition of DBE-based Paint Stripping Formulations

Key ingredients (and supporting components)	CAS Number	Percentage in formulation	Relevant applications and other notes
Dibasic esters (mixture)	**106-65-0 1119-40-0 627-93-0 (95481-62-2)**	**25-95%**	PROF (architectural, graffiti removal), CON
N-methyl-2-pyrrolidone	872-50-4	8-35%*	PROF (wall stripping)
Triethylphosphate	78-40-0	2.5-10%	IND, PROF, CON
Acetone 1,2,4-trimethylbenzene Butanone Mesitylene Pentyl acetate Pine oil Propan-2-ol Solvent naphtha	67-64-1 95-63-6 78-93-3 108-67-8 628-63-7 8002-09-3 67-63-0 64742-95-6	25-50 1-2.5 10-25 <1.0 2.5-10 2.5-10 10-25 2.5-10	Furniture finish remover
Base formulations			
DBE-2 N-methyl-2-pyrrolidone Aromatic naphtha solvent Thickener Potassium oleate in water		40% 15% 40% 0.5-2% 4%	Base formulation effective for the removal of latex acrylic enamel, nitrocellulose lacquer, vinyl acrylic interior, polyurethane varnish and a modified tall oil epoxy
DBE-2 N-Methyl-2-pyrrolidone C_{13}-C_{20} isoparaffinic and cycloparaffinic hydrocarbons Potassium oleate (50% in H_2O) Methylcellulose		47% 18% 31% 3% 0.8-1.0%	Base formulation effective for the removal of latex acrylic enamel, nitrocellulose lacquer, vinyl acrylic interior, polyurethane varnish and a modified tall oil epoxy

33 The alternatives are grouped on the basis of the active ingredient i.e. the ingredient that performs the removal of paint. If there exist two or more ingredients in the formulation that may be considered as 'active', we choose to characterise the formulation on the basis of the ingredient with the highest concentration.

Table 5.8: Composition of DBE-based Paint Stripping Formulations			
Key ingredients (and supporting components)	**CAS Number**	**Percentage in formulation**	**Relevant applications and other notes**
DBE-2 Dimethylsulphoxide Dipropylene glycol methyl ether Ethyl-3-ethoxypropionate Water Thickener Surfactant		35% 28% 25% 5% 1% 1% 5%	Base formulation effective for the removal of latex acrylic enamel, nitrocellulose lacquer, vinyl acrylic interior, polyurethane varnish and a modified tall oil epoxy
DBE-2 Propylene carbonate N-methyl-2-pyrrolidone Bentonite		15.6% 15.6% 31.3% 37.5%	Base formulation effective for the removal of latex acrylic enamel, nitrocellulose lacquer, vinyl acrylic interior, polyurethane varnish and a modified tall oil epoxy
DBE-2 Ethyl-3-ethoxypropionate (EEP) or N-methyl-2-pyrrolidone		60% 40%	These base formulations may be used hot for dip stripping and generally do not require thickeners or soaps
DBE-3 Aromatic naphtha solvent N-methyl-2-pyrrolidone Potassium oleate Thickener		40% 40% 15% 4% 0.05-2%	Base formulation for graffiti removal
DBE N-methyl-2-pyrrolidone Cycloparaffinic solvent		50% 40% 15%	Base formulation for graffiti removal
Source: Consultation and Internet literature ** Concentrations up to 10% appear to be suitable for consumer products and some professional uses; concentrations of 25-35% are common for professional uses*			

5.7.3 Human Health and Environmental Hazards

As shown in Table 5.5, DBEs may be considered to be skin and eye irritants (depending on the component and end-point they could be slightly to highly irritating) and marginally more toxic to the aquatic environment than DCM. Nevertheless, SOCMA (2002) advises that, for aquatic organisms, DBEs are "slightly" to "practically non-toxic" in fish and aquatic invertebrates. Finally, while inhalation may cause reversible blurring of vision, there is no evidence of carcinogenicity or mutagenicity.

Table 5.6 shows that the vast majority of Member States do not have in place OELS for DBEs; Sweden is the exception to the rule with considerable low OEL values for all three components of the DBE mixture. The literature of a manufacturer advises that all DBE formulations[34] should be used only in well-ventilated areas (Invista, 2006b).

34 This refers to the base formulations suggested by the manufacturer of DBEs.

Exposure Information

Some information has been received on the exposure levels for DBEs during use of water-based DBE paint strippers[35]. The UK manufacturer of these water-based formulations has advised us that this technology has been the basis of a product that can be used during the safe removal of lead painted cables. This product was developed following discussions with a large UK telecommunications company which is interested in removing old lead painted cables in telephone exchanges. During the upgrade of a telephone exchange, it is necessary to remove all cotton braided cable (CBC) and older equipment in order to allow fitting of new network components. These cables are known to have lead-based paint on the outer layer.

The telecommunications company is very keen to control exposure of its personnel to hazardous substances at source recognising that PPE, although required as a means of control in many situations, should not be relied upon as a sole means of control. The company identified the aforementioned water-based formulation as a potential candidate for removal of CBCs from telephone exchanges. Following discussions between the two parties, the Institute of Occupational Medicine in Edinburgh (UK) was commissioned to undertake laboratory testing of the formulation in 2005, which indicated that this water-based product could significantly reduce the airborne concentrations of lead (IOM, 2006).

Following the results of the laboratory tests, a site trial was arranged to be carried out at a real telephone exchange in Edinburgh, UK, to evaluate the methods *in situ*. Airborne monitoring carried out during the one-week trial indicated that the water-based product could reduce exposure to dust and lead to concentrations far lower than those experienced during traditional removal methods. Samples collected to determine the exposure of the engineers to airborne total dust showed average concentrations of approximately 1/10th of the lead in air standard. Results for inorganic lead showed personal concentrations, in general, to be <0.01 mg/m^3 (IMO, 2006).

Of most relevance to this present report is the fact that sampling was undertaken for airborne concentrations of both key components of the formulation, one of which is dimethyl adipate (a DBE). Airborne samples were collected on treated filters and analysed in accordance with a modification of NIOSH method 5304, as used during the laboratory tests. With regard to dimethyl adipate, nine personal and one static samples were analysed to determine the concentrations during use of the high volume low-pressure spray. The concentrations measured during the use of the hand pump were variable, ranging from <0.01-0.16 ppm, with an average of 0.09 ppm. Again the lowest concentrations were measured during application by brush (IOM, 2006).

The report by the IOM notes that in the case of exposures to both dimethyl adipate, the actual airborne concentrations measured do not equate directly to personal exposure.

35 The same company offer this product in microemulsion form mainly for industrial removal of paint from metal surfaces and degreasing. This microemulsion is different to that promoted by the manufacturer of DBEs which was mentioned earlier in this sub-Section.

During a normal 7-8 hour shift the engineers worked two 3-hour periods. In most cases application of the lead removal product would be restricted to either the morning or afternoon period, not both. Personal exposure, as referenced to an 8-hour TWA would therefore be lower than the actual measurements. The 8-hour TWA for the dibasic ester during application by hand pump would be reduced to approximately 0.03 ppm (note that the 8-hour TWA for the other key component of the formulation would be even lower) (IOM, 2006).

It is important to note that this product was used in the laboratory tests and the site trial as a product specifically developed and aimed at the safe removal of CBC in telephone exchanges, rather than a typical paint stripper used in the ways and processes described in the rest of this report. The manufacturer of the product, however, has advised that "*this product is effective by softening the paint and encapsulating the lead particles within the emulsion. This would not happen if it were not a paint remover/softener. This product, which was developed specifically for this customer, has the same ingredients as our paint remover, graffiti remover etc*".

DBE and Impurities

We have been advised that an issue arose recently (October-November 2006) with the presence of dimethyl sulphate (CAS No. 77-78-1) as an impurity in DBEs sold to formulators of paint strippers. This substance is classified as a carcinogen category 2 under Annex 1 to Directive 67/548/EEC.

The information received by a formulator of both DCM-based and DCM-free paint strippers was that the manufacturer of DBEs had to recall the product and contact their customers to ask them to check the product labelling and whether they needed to recall the product.

We contacted the DBE manufacturer in question and we were advised that the problem arose due to a manufacturing issue that was resolved quickly and is of no effect in the continued use of DBEs in paint stripping formulations. According to the manufacturer, the company itself detected dimethyl sulphate in DBEs manufactured in the UK at levels that made it subject to certain classification and labelling requirements under Annex 1 of Directive 67/548/EEC. Following discovery, the manufacturing process was immediately modified to address this matter, and once completed, the company resumed production of DBEs from the UK production site with dimethyl sulphate levels well below the threshold concentration for classification. As further assurance, each lot is analysed, and the level of dimethyl sulphate is listed on the certificate of analysis for DBEs produced in the UK. The issue was limited to one manufacturing location only and did not involve product from other manufacturing facilities of this company.

We have also been advised that there are at least four different EU manufacturers of DBEs while formulators of paint strippers are also able, if they so wish, to import DBEs from non-European manufacturer. Taking this into account and considering that the problem arose for a short period in only one of the manufacturing plants of the company in question, it can be concluded that this is not a general problem with DBEs which might affect the overall use of these substances in paint stripping formulations. However, this problem does highlight the need for good manufacturing practices.

5.8 Benzyl Alcohol

5.8.1 Identity

Benzyl alcohol is a colourless liquid with a mild aromatic odour and sharp burning taste. It has a flash point of 94°C (US Navy, 2003b).

5.8.2 Technical Characteristics

Benzyl alcohol (and its blends) has been identified as substitutes for DCM-based paint strippers. They can broadly be divided into two (US Navy, 2003b):

- ***acidic formulations***: acid benzyl alcohol strippers contain approximately 25 to 35% benzyl alcohol, 10 to 15% formic acid (which acts as an accelerator) and have a pH of 2.5. The acid strippers are generally safe for all metals, except high strength steel (which the have the potential to embrittle[36]) or magnesium. Non-metallic surfaces, such as fibre reinforced composites and rubber boots and seals, must be masked or removed (as when stripping with DCM); and

- ***basic formulations***: alkaline benzyl alcohol strippers contain approximately 30 to 50% benzyl alcohol, 5 to 10% amine or ammonia compounds and has a pH of 11.

Neutral benzyl alcohol stripper may also be used (US Navy, 2003b).

These formulations find particular application in the aircraft stripping industry where they dominate the market having replaced DCM-based paint stripping to a significant extent.

Benzyl alcohol solutions have excellent adherence to vertical surfaces and remain active for approximately four hours. Acidic benzyl alcohol solutions typically take slightly longer to delaminate the paint compared to DCM. Alkaline benzyl alcohol solutions take even longer (US Navy, 2003b).

Testing undertaken in the US suggests that benzyl alcohol-based paint strippers may show the following limitations (US Navy, 2003b):

- very slow reaction rate below 18°C;
- additional time required to strip very thick coatings (over 0.02 cm) and water-borne applied primers as opposed to solvent primers; and

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36 It is reported that, as a result, some manufacturers, owners, and the US Navy prohibit the use of acid strippers (US Navy, 2003b)

- additional time required to strip coatings with a very aggressive conversion coating below the primer.

Following the above, using benzyl alcohol solutions may increase the time required to strip equipment by approximately 25%. In addition, it is more labour intensive than DCM (US Navy, 2003b).

In comparison to DCM, the US Navy (2003b) counts the following benefits from the use of benzyl alcohol formulations:

- they reduces the risks from exposure to DCM;
- they can be effective strippers for several paint systems; and
- they can be applied using existing spray equipment.

Composition of Benzyl Alcohol-based Paint Strippers

Table 5.9 outlines a selection of compositions of benzyl alcohol-based paint strippers. The 'active' ingredients[37] are displayed in bold and the last column to the right provides any available information on the applicability of the various formulations (IND: industrial uses, PROF: professional uses; CON: consumer uses). The table below is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.

5.8.3 Human Health and Environmental Hazards

Benzyl alcohol is a VOC. According to Table 5.5, benzyl alcohol is classified as harmful by inhalation and if swallowed, appears to have sensitising properties and is more toxic to the aquatic environment than DCM. Table 5.6 shows only few countries as having OELs for benzyl alcohol. Where this is the case, the values are lower to those of DCM, but again, benzyl alcohol is not as volatile as DCM.

[37] The alternatives are grouped on the basis of the active ingredient i.e. the ingredient that performs the removal of paint. If there are two or more ingredients in the formulation that may be considered as 'active', the formulation is characterised on the basis of the ingredient with the highest concentration.

Table 5.9: Composition of Benzyl Alcohol-based Paint Stripping Formulations			
Key ingredients (and supporting components)	**CAS Number**	**Percentage in formulation**	**Relevant applications and other notes**
Benzyl alcohol	**100-51-6**	**20 - >60%**	IND (aerospace, multimetal)
Dibasic esters	1119-40-0	25%	PROF
Hydrogen peroxide (aqueous emulsions)	7722-84-1	>5%	
Formic acid	64-18-6	>5%	
Distillates (petroleum), catalytic reformer Glycolic acid Propan-1,2-diol	68477-31-6 79-14-1 57-55-6	10 % 5 % 5 %	
Gamma-butyrolactone C_9/C_{11} Fatty alcohol ethoxylate	96-48-0 68439-46-3	< 10% < 1%	Graffiti removal (gel)
Water Anisole Amyl acetate Formic acid	 64-18-6		
Water Methylbenzotriazole Tetrapropylbenzene Ammonia Diethanolamine borate			
Source: Consultation *Percentage in formulation and CAS Number provided where available.* *This table is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.*			

5.9 Dimethyl Sulphoxide (DMSO)

5.9.1 Identity

DMSO is used industrially as a reaction solvent, polymerisation solvent, in antifreeze products, hydraulic fluids, paint and varnish removers, as a pharmaceutical solvent, as an analytical reagent, as a clean-up solvent and in the manufacture of synthetic fibres, industrial cleaners and pesticides. In medicine it is used as a treatment for interstitial cystitis, in the preservation of cells at low temperatures, in the diffusion of drugs into the bloodstream by topical applications, as an anti-inflammatory agent and as an analgesic. It is also used in veterinary medicines (DSPA, 2003).

Consultation with a manufacturer[38] of both DCM and DMSO, suggests that in Europe the sales of DMSO for all applications could be as high as 10,000 tonnes (this is an estimate) and the main uses are in agrochemicals and pharmaceuticals.

[38] Note that separate sections of the company appear to be manufacturing DCM and DMSO.

5.9.2 Technical Characteristics

DMSO is in the class of potent solvents known as the "dipolar aprotic solvents". This class also includes NMP, dimethylformamide and dimethylacetamide. DMSO has a very broad range of miscibility with most common organic solvents such as alcohols, esters, ketones, chlorinated solvents and aromatic hydrocarbons providing a wide choice for formulation effectiveness. Compatibility with most acids and with bases, such as, hydroxides, alkoxides, ammonium and amines, furthers this versatility. DMSO is miscible in all proportions with water, which provides water rinseability when used alone or in blends. DMSO has wide use in many difficult clean-up and stripping applications involving highly cross-linked polymers, a fact that strongly suggests its potential utility for removal of 'difficult' coatings such as those used on aircraft (Dishart & McKim, 2003).

According to a manufacturer of the substance, properties of DMSO that provide key benefits to DMSO-based paint strippers are (Dishart & McKim, 2003):

- a high flash point which equates to a low fire hazard potential (this affects both its use and storage);
- a very low vapour pressure which greatly minimises solvent loss, emissions to the atmosphere and employee exposure; and
- a clear and odourless product. Past concerns about DMSO odour were related to impurities, which have reportedly been eliminated by quality improvements in the standard production product. A European manufacturer has also confirmed that an old odour problem has recently been resolved with better manufacturing practices that reduce the presence of impurities.

A manufacturer claims that the low molecular volume of DMSO allows for good diffusion in the paint film. This penetration ability is greatly improved when DMSO is associated to a non-protic co-solvent of medium polarity. All protic or polar solvents have high cohesion energy due to the large number of hydrogen or dipolar bonds present in the solution. This "group" energy constitutes an obstacle to the penetration of molecules into the film. The addition of a non-protic co-solvent of medium polarity will facilitate the diffusion within the film by reducing this energy (Arkema, 2007b).

DMSO may be used in combination with several other solvents in the formulation of paint strippers such as NMP, DBE and dimethylformamide (Dishart & McKim, 2003) and is promoted in Europe as a solvent suitable for paint strippers and as a good replacement for NMP, mainly on the basis of similar polarity (Arkema, 2007b).

When formulating DMSO-based paint stripper, the following family of co-solvents can be used:

- ketones (methyl ethyl ketone - MEK, methylisobutylketone - MIBK, ethylamylketone - EAK, etc.);

- ethers;
- esters; and
- ‘green’ solvents.

Other components of formulations usually include (Arkema, 2007b):

- ***activators***: these are small and very polar molecules which will help in breaking the adhesive bonds between the paint film and the substrate. They show a strong affinity towards polar surfaces (wood, metal, glass);

- ***thickeners***: it is preferable to use cellulosic thickeners such as hydroxypropylcellulose soluble in any polar organic solvents; and

- ***evaporation retardants***: this could be methyl ethyl ketone (MEK).

Table 5.10 presents the composition data received through consultation.

Table 5.10: Composition of DMSO-based Paint Stripping Formulations

Key ingredients (and supporting components)	CAS Number	Percentage in formulation	Relevant applications and other notes
Dimethylsulphoxide	**67-69-5**	**20-80%**	PROF (architectural), CON
N-butylacetate Naphtha (petroleum), hydrotreated heavy Fatty alcohol ethoxylate 5 EO	123-86-4 64742-48-9 	25-50% 2.5-10% <2.5%	CON
N-methyl-2-pyrrolidone Ethyl ethoxy propionate Propylene carbonate Silica, amorphous	872-50-4 763-69-9 108-32-7 	2.5-10% 10-25% 2.5-10% 2.5-10%	

Source: Consultation
Percentage in formulation and CAS Number provided where available.
This table is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.

With a DMSO-based paint stripping formulation, swelling of the old paint is observed and this leads to the formation of flakes or blisters. To obtain a bare surface, the substrate may be washed with a water jet.. The process is essentially a physical one, and dissolution of the paint is rarely observed. When removing an old paint film, it does not require water treatment at the end of the process in most applications. DMSO-based formulations are reportedly suitable for both brush application and tank dipping (Arkema, 2007b).

On the other hand, it has been suggested that DMSO has a relatively high melting point (18.5°C according to the relevant IUCLID datasheet); this could make its handling by the formulators in winter rather more complicated.

Worker Protection Measures

The Safety Data Sheet of the manufacturer includes the following exposure/personal protection controls (Arkema, 2006):

- ***respiratory protection***: in case of insufficient ventilation, wear suitable respiratory equipment. Low concentrations or short activity & high concentrations or prolonged activity: self contained breathing apparatus;
- ***hand protection***: nitrile rubber gloves, surface thickness 0.75 mm; and
- ***eye protection***: safety glasses.

A search on the Ansell Europe Internet page suggests that there are several types of gloves that provide maximum protection (Protection Index = 6) against DMSO. These are neoprene and polyurethane coated gloves. Nitrile gloves appear to have a breakthrough time of 10 minutes or less, although their thickness appears to be considerably smaller than that recommended by Arkema above (0.75mm).

It is of interest that the manufacturer suggests that breathing apparatus should be used in certain cases; this bears a significant resemblance to working with DCM.

5.9.3 Human Health and Environmental Hazards

The available studies on aquatic toxicology endpoints demonstrate that DMSO has low toxicity for fish, aquatic invertebrates and plants. DMSO has very low toxicity as evidenced by data from all mammalian health endpoints, often obtained from several species using multiple routes of exposure; the LD_{50} is approximately 20 mg/kg and the repeat dose NOEL is approximately l g/kg, with ocular toxicity as the most consistent and sensitive endpoint.

Notably, because of its low toxicity profile DMSO is used in many unique applications, such as, a neutral solvent in the Ames mutagenicity test and in human and animal medical treatments (Dishart & McKim, 2003).

There is no evidence of developmental toxicity; however, whilst a number of genetic toxicity tests are generally negative, there is one study that has shown evidence of chromatid breaks in rats. This has been demonstrated in data submitted by a consortium of producers to the US EPA in 2005. It is not clear whether this issue has been addressed or explained by the companies since then.

Another issue that has been highlighted by some consultees is that DMSO has a high skin penetration rate, and is used as a carrier for drug administration by this route. It has been argued that use of DMSO in a paint stripper could carry the risk that toxic constituents of a paint film may be carried into the body. During consultation, Arkema (that manufactures DMSO) has insisted that the skin penetration rate of DMSO corresponds to that of NMP which is used extensively in alternative paint stripping formulations.

5.10 1,3-Dioxolane

5.10.1 Identity

1,3-dioxolane is a cyclic reaction product of ethylene glycol and formaldehyde which can exhibit behaviour typical of ethers or acetals as conditions dictate. It is a colourless liquid that is miscible with water and most common organic solvents. It is a very good solvent for lacquers and resins and can be used for paint removers and thinners (Ferro, 2007).

Other uses of 1,3-dioxolane include stabiliser for glues, impregnating resins and dispersions, copolymerising agent with trioxane in the manufacture of polyacetal resins, use in adhesives, reaction solvent for pharmaceutical manufacturing, replacement for many chlorinated solvents, lithium battery electrolyte solvent component and in the manufacture of polycarbonate/polyester membrane filters (Ferro, 2007).

5.10.2 Technical Characteristics

Under neutral or basic conditions, 1,3-dioxolane has excellent solvent performance characteristics and should be considered as an attractive substitute for chlorinated solvents, ethers and ketones (Ferro, 2007).

A manufacturer claims that 1,3-dioxolane has successfully substituted ethylene dichloride, DCM and tetrahydrofuran (THF) in specific applications. It can also substitute DMSO and possibly methyl ethyl ketone (MEK).

1,3-dioxolane is often used with methylal (also known as dimethoxymethane, CAS No. 109-87-5) to achieve effective paint removal. A Belgian manufacturer of both substances argues that combinations of 1,3-dioxolane and methylal act "*as fast and as visible as DCM*". The two classic paint remover types, abrasive or for rinsing, are easy to formulate with these two solvents, as they are miscible with water (methylal is only partially), have a low toxicity and are biodegradable, according to the manufacturer (Lambiotte, 2007).

The alleged advantages of formulations of 1,3-dioxolane and methylal are (Lambiotte, 2007):

- ***high solvent power***: particularly of 1,3-dioxolane towards polyurethane, epoxy, acrylic resins (even reticulated) and towards plasticisers used in paints;
- ***strong polarity***: this applies to 1,3-dioxolane and it facilitates the loosening of the film and ensures the rupture of reticular bonds between polymer chains;
- ***small molecular size***: this allows for rapid diffusion and penetration of the paint film; and

- ***low toxicity and ecotoxicity, biodegradability and miscibility with water*** (due to its miscibility in water, it is possible to formulate paint removers for a specific class of paints (e.g. latex, PVA, interior paints, etc.). It should be noted that the information presented in Table 5.5 (and discussed further below) does not support the manufacturer's assertion on biodegradability.

Formulations based on 1,3-dioxolane may be neutral, acidic or alkaline. Table 5.11 outlines information on the composition of 1,3-dioxolane formulations that has been collected through consultation and through a review of readily accessible literature (for instance, see the base formulations by Lambiotte).

Lambiotte claims that the neutral paint stripping formulation are very efficient in removing coatings, however their efficiency could still be improved by the addition of surfactants and synergists (Lambiotte, 2007). The neutral base formulations could remove the following coatings in the time indicated below (this is the "time required before possible removal in minutes") (Lambiotte, 2007):

- polyurethane paint on wooden floors: 3 minutes;
- polyurethane paint on metal floors: 3 minutes;
- acrylic paint for wooden façades: 10 minutes;
- acrylic paint for metal façades: 5-10 minutes;
- epoxy 2-component paint on wood: 20-60 minutes;
- epoxy 2-component paint on metal: 20-60 minutes;
- classic alkyd paint on wood: 5 minutes;
- classic alkyd paint on metal: 3 minutes; and
- paint on coachwork: 15 minutes.

With regard to acidic formulations, the incorporation of formic acid and acetic acid enhances penetration into the paint film; however there is always the issue of corrosion of metals and the unpleasant odour typical of these acids (Lambiotte, 2007).

With alkalis in the formulation, the swelling of the paint increases and the efficiency of the paint stripper is strengthened by hydrolysis of the binding agent. Triethanolamine, monoethylamine or sodium metasilicate could be substituted instead of potassium hydroxide. With the addition of potassium oleate (with ±4%) or soda alkylarylsulphonate the rinsing becomes easier and more efficient (Lambiotte, 2007).

Controls on Worker Exposure

The manufacturer recommends that a paint remover based on one of the above formula examples must always be used in a well ventilated place (1,3-dioxolane may not be as volatile as DCM but it has a significantly high vapour pressure), away from every flame or source of ignition. Gloves and safety goggles should be worn, although no specific type of gloves is recommended (Lambiotte, 2007).

Notably, where national OELs for 1,3-dioxolane are in place (see Table 5.6), these are lower than those for DCM.

Key ingredients (and supporting components)	CAS Number	Percentage in formulation	Relevant applications and other notes
1,3-dioxolane	**646-06-0**		
Acetone	67-64-1		
1,3-dioxolane	**646-06-0**	**<40%**	
Dimethoxymethane (methylal)	109-87-5	< 20%	
Naphtha heavy, desulphurised	64742-82-1	>10 - <25%	
N-methyl-2-pyrrolidone	872-50-4	< 20%	
Butane	106-97-8	< 10%	
Isobutane	75-28-5	< 5%	
Propane, liquefied	74-98-6	< 5%	
Sodium dioctyl sulphosuccinate	577-11-7	< 5%	
1,3-dioxolane	**646-06-0**	**<40%**	
Dimethoxymethane	109-87-5	<20%	
Naphtha, heavy	64742-82-1	10-25%	
Base formulations			
1,3-dioxolane	**646-06-0**	**68%**	Base formulation for neutral paint stripper
Dimethoxymethane (methylal)	109-87-5	24%	
White spirit		4%	
Methylcellulose		2%	
Paraffin wax		2%	
1,3-dioxolane	**646-06-0**	**56%**	Base formulation for neutral paint stripper
N-methyl-2-pyrrolidone	872-50-4	40%	
Methylcellulose		2%	
Paraffin wax		2%	
1,3-dioxolane	**646-06-0**	**86%**	Base formulation for acidic paint stripper
Formic acid		4%	
Acetic acid		4%	
Water		4%	
Methylcellulose		2%	
1,3-dioxolane	**646-06-0**	**67%**	Base formulation for alkaline paint stripper
Dimethoxymethane (methylal)	109-87-5	23%	
Water		5%	
Potassium hydroxide		2%	
Methylcellulose		2%	

Table 5.11: Composition of 1,3-dioxolane-based Paint Stripping Formulations

Source: Consultation and Literature
Percentage in formulation and CAS Number provided where available.
This table is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.

5.10.3 Human Health and Environmental Hazards

As shown in Table 5.5, 1,3-dioxolane has some important differences compared to DCM. It is highly flammable and this needs to be taken into account when handling 1,3-dioxolane formulations. According to a manufacturer, when 1,3-dioxolane and methylal (both of which are flammable solvents) are formulated with acid or alkaline additives, water and thickeners, the flash point of the mixture can change from +10 to +30°C depending on the composition of the formulation (Lambiotte, 2007).

Moreover, the substance has been associated with some reprotoxic effects, has skin irritancy potential and appears not to readily biodegrade (although a manufacturer argues the opposite for both 1,3-dioxolane and methylal – Lambiotte, 2007). Its aquatic toxicity, however, is comparatively low.

5.11 Alkalis (Sodium Hydroxide)

5.11.1 Identity

Caustic strippers are pastes or semi-liquids that employ sodium hydroxide (lye) or potassium hydroxide, often mixed with trisodium phosphate, to loosen paint (Old House Journal, 2001).

5.11.2 Technical Characteristics

There are two types of alkaline paint removal systems (Percival, 2005):

- an aqueous sodium hydroxide solution within a dipping tank for detachable components (for industrial processes); and
- a formulated paste to be applied *in situ* over walls, doors and structural features.

The composition and use characteristics of these products are (Percival, 2005):

Dipping tank NaOH solution

- Typically 10-20% w/w NaOH solutions;
- full immersion of painted components in a free flowing solution;
- only suitable for doors, fittings & furniture which can be relocated;
- dipping is an industrial use, although neat caustic is sold through retailers for amateur (DIY) uses;
- intended uses are as a drain cleaner or oven cleaner; and
- it is also recommended for use as a paint remover.

Caustic paste

- Strongly alkaline, viscous paint remover formulated to enable *in situ* application onto fixed structures;
- typically contains 8-10 % w/w NaOH as a ready to use paste;
- applied as a temporary coating over the painted surface;
- covered with a protective sheet to prevent drying out; and
- removal 24 hours later to reveal bare substrate beneath.

The advantages and drawbacks of caustic paste include (Percival, 2005, and other sources as indicated):

Advantages of caustic paste

- Removes up to 30 coats of paint in a single 24 hour application;
- suitable in confined locations where ventilation is restricted & odours are prohibited;
- suitable for alkyd resin paints (synthetic resins) and for oil-based paints (older coatings) (Test, 2005);
- preferred for the removal of old paint from ornate surfaces such as decorative plaster mouldings, carved timbers, stone features and wrought ironwork;
- enables the contained removal of lead based coatings without risk of liberating lead contamination to the environment and operatives;
- effective in removing oil-based alkyd varnish, gloss & undercoats and water-based vinyl emulsions (amongst the most common coating types in the UK); and
- in the event of an accidental spillage, its viscous paste structure and low volatility reduces the risk of widespread contamination.

Drawbacks of caustic paste

- Causes burns in contact with skin;
- will not remove sprayed graffiti, acrylic paints, cellulose lacquers, epoxy coatings, chlorinated rubbers, polyurethanes, powder coatings & traffic paints;
- weakens & damages Gesso[39] & natural resin bound plasters;
- corrodes & discolours aluminium or zinc based metal substrates;
- irreversibly darkens and damages hardwood timbers especially hardwoods such as oak, ash and any type of wood veneer finish;
- surfaces to be re-coated require washing and neutralisation with a mild acid solution (acetic acid) to remove residual alkalinity;
- when this neutralisation process is left out, any new coatings that are applied to the substrate may start to peel off, and the treated area would leech out white efflorescent and toxic salts (ECOSolve, 2007);
- less effective in temperatures under 10°C, but high humidity typically has little effect (PaintPRO, 2000); and
- total duration of task (up to 3 days) means treated areas must be evacuated and quarantined to prevent accidental contact with passers-by.

Controls on Worker Exposure

It is very important for the user to avoid skin and eye contact when using caustic alkalis. This implies the use of gloves that fit properly and are appropriate for caustic alkalis. Also, appropriate protective clothing and goggles are needed.

39 "Gesso" is the Italian word for "chalk" and is a powdered form of the mineral calcium carbonate used in art. Modern acrylic Gesso is actually a combination of calcium carbonate with an acrylic polymer medium and a pigment. Acrylic gesso is a modern art material, and is used as a primer for oil painting and acrylics. Gesso is also used by sculptors, to prepare the shape of the final sculpture (fused bronze) or directly as a material for sculpting.

The following PPE is described by a UK formulator of caustic products (Percival, 2005):

- rubber/PVC heavy duty protective boots;
- protective PVC overalls with fastened wrists & ankles and hood;
- heavy duty rubber/PVC gauntlets with fastened closures up to elbow length; and
- full-face protection using an alkali resistant visor, worn beneath a hard PVC helmet.

The formulator notes that respiratory protection is not required as even in confined spaces the risk of inhaling vapours or dust is minimal providing temperatures are maintained at ambient conditions (Percival, 2005).

The Ansell Europe Internet site shows that several types of gloves provide adequate protection (Protection Index = 6) to sodium hydroxide. These include latex gloves, neoprene gloves, natural rubber gloves, EVA laminate gloves etc.

5.11.3 Human Health and Environmental Hazards

Compared to DCM, sodium hydroxide has higher toxicity to the aquatic environment but still it is considered to be of limited ecotoxicity. Caustic-based stripper systems are hazardous to the user due to their corrosive properties. Furthermore, some caustic-based stripper systems contain other ingredients including, in some cases, hazardous solvents. Caustics, since they are corrosive, they can cause severe burns to skin and eyes, even on short contact. The acid-based solutions used for neutralisation are also corrosive, cause skin burns and may be even more toxic than the caustic products themselves (ECOSolve, 2007).

5.12 Other Alternatives

Table 5.12 summarises the information collected through consultation on the composition of other alternatives that do not fall under any of the categories above.

Table 5.12: Summary of Potential Alternative Paint Stripping Formulations

Type of alternative	Key ingredients (and supporting components)	CAS Number	Percentage in formulation	Relevant applications and other notes
DMF-based systems	**Dimethylformamide***	**68-12-2**	**Up to 50%**	IND
	Xylene	1330-20-7		
Aliphatic or aromatic hydrocarbons-based systems	**Xylene** Methyl ethyl ketone N-methyl-2-pyrrolidone	**1330-20-7** 78-93-3 872-50-4	**50-75%** 30-40% 5-10%	IND, PROF, CON
Acid-based systems	**Phosphoric acid** **Formic acid**	**7664-38-2** **64-18-6**		IND, PROF
Other organic solvent-based systems (mixtures of	**2-methoxymethylethoxypropanol**	**34590-94-8**	**10-20%**	IND, PROF, CON
	Triethanolamine	**102-71-6**	**1-10%**	"*Same as DCM*"
	Monoethanolamine	**141-43-5**	**10-50%**	IND (aerospace)

Table 5.12: Summary of Potential Alternative Paint Stripping Formulations				
Type of alternative	**Key ingredients (and supporting components)**	**CAS Number**	**Percentage in formulation**	**Relevant applications and other notes**
alcohols, glycol ether, etc.)	**Dipropyleneglycol monoethyl ether** N-methyl-2-pyrrolidone Naphtha (petroleum), hydrotreated heavy Oxyalcohol ethoxylate Dodecylsuplhonate amine salt	**15764-24-6** 872-50-4 64742-48-9 69011-36-5	10-25% 2.5-10% 2.5-10% 2.5-10% ≤2.5%	
	2-(2-buthoxyethoxy) ethanol Sodium hydroxide	**112-34-5** 1310-73-2	**15 %** 2 %	
	2-butoxyethanol Sodium hydroxide Sodium xylene sulphonate Sodium metasilicate C_9/C_{11} Fatty alcohol ethoxylate	**111-76-2** 1310-73-2 1300-72-7 6834-92-0 68439-46-3	**<10%** <2% <5% <5% <5%	Graffiti removal
	Methyl ethyl ketone N-methyl-2-pyrrolidone D-Limonene Xylene Ethylbenzene Petroleum naphtha	**78-93-3** 872-50-4 5989-27-5 1330-20-7 100-41-4 64742-48-9	**50-100%** 10-25% 0-2.5% 2.5-10% 2.5-10% 0-2.5%	Paint stripper for wood surfaces coated with acrylic/alkyd paints, varnishes or stains
	2-(2-butoxyethoxy)ethanol Formic acid	**112-34-5** 64-18-6	**10-30%** <1%	
Acetone or methanol-based formulations	**Acetone** **Methanol**	**67-64-1** **67-56-1**		PROF, CON
	Toluene	108-88-3		
	Acetone Butan-1-ol Cyclohexanone Ethanol 1,3-dioxolane Petroleum naphtha Paraffin waxes	**67-64-1** 71-36-3 108-94-1 64-17-5 646-06-0 64742-48-9 64742-51-4	**25-50%** 2.5-10% 10-25% 10-25% 10-25% 0-2.5% 0-2.5%	Paint stripper for all surfaces (except plastic derivatives) coated with paints, varnishes, stains or glues
D-limonene-based systems	**D-Limonene**	**5989-27-5**		

Source: Consultation
Percentage in formulation and CAS Number provided where available.
This table is provided for information only and should not be considered to display an exhaustive collection of potential alternative paint stripping formulations.
** Formulations based on dimethylacetamide (CAS No. 127-19-5 - contains a methyl group in the place of a hydrogen compared to dimethylformamide) have also been suggested.*

5.13 Evidence on the Suitability of Alternatives

5.13.1 Views of Stakeholders on the Technical Suitability of Alternative Paint Strippers

Conflicting views have been received on the availability and technical suitability of alternative paint strippers.

Key points in taking these inputs into account are:

- a significant portion of manufacturers of paint strippers are involved in the manufacture of both DCM-based and DCM-free paint strippers. The views of these companies towards a potential restriction on the marketing and use of DCM-based paint strippers are variable and mainly depend on how important the contribution of DCM-based products is to their turnover (i.e. where this contribution is small, a manufacturer is less concerned about a potential restriction) and whether the company has already developed alternative paint strippers and has established (or hopes to establish) a presence in the paint stripper market; and

- the input received from companies involved in professional uses of DCM-based paint strippers has largely been made by enterprises located in the UK, where the use of DCM-based paint strippers is quite extensive. It is of note that a group of UK/Irish formulators of paint strippers organised in 2005 a survey of companies involved (primarily) in professional uses asking for their views on what products they use and for which applications, what alternatives they have used, what criteria they would use in choosing a paint stripper and what their views are on a potential restriction on DCM-based paint strippers. The results of this survey are summarised in Annex B (in the Section relevant to the UK at the end of the Annex). It is of interest that 48% of respondents said that DCM-based paint strippers cannot be effectively replaced by alternatives while 30% of the sample of UK/Irish companies involved in professional uses believes that DCM-based paint strippers can effectively be replaced by DCM-free pint stripping formulations/methods[40].

Views of Individual Companies

Within RPA's consultation exercise, some companies have indicated that alternative paint strippers may face difficulties in the following situations:

- industrial applications where stripping resistant films have traditionally been removed by thickened DCM-based products. This includes applications of thickened products in the cleaning of spray booths or floors in paint shops), where alternatives have been suggested to be too weak for removal of 2-component paints or stoving enamels;

- professional applications where conservation work needs to be undertaken on historical buildings. A professional user located in the UK has suggested that "*caustic products can cause chemical imbalances in some substrates. Many English Heritage surveyors will specifically ban caustic based products for this reason*". In subsequent discussions with the company, the alleged poor performance of other non-caustic alternatives was suggested; and

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40 This 30% is higher than the 10% presented in the November 2005 Paint Stripping Forum in Brussels which was at the time based on a total of 50 responses.

- for professional and consumer uses, a manufacturer of DCM-based paint strippers has suggested that his understanding is that "*alternative systems are ineffective in removing alkyd paints. These types of paints have been used in the UK for decades, and this explains the poorer performance of alternative systems on traditional gloss paints. In the UK, methylene chloride paint removers are used effectively to remove water based masonry paints, water based varnishes, water based gloss paints, etc. Standard emulsion paints in our experience are rarely removed*".

Consultees supplying or in favour of using DCM-based paint strippers agreed that alternatives may be suitable for use:

- for industrial applications in dip tanks, steel stripping may be served by aqueous alkaline products (mixtures of potassium hydroxide solution) or solvents (alcohols, glycols and surfactants) at a working temperature of 80-90°C. For aluminium, high boiling solvents may be used (such as NMP, glycol ethers, additives (e.g. NaOH, amines)) at a working temperature of 80-90°C (this is based on information from a manufacturer of both DCM-based and DCM-free paint strippers);

- for professional and consumer uses, the removal of single layers, or maximum 2-3 layers, of modern acrylic coatings (information from a UK company involved in professional uses); and

- for professional and consumer uses, a change to DCM-free products is possible if air drying paints (e.g. dispersion paints) have to be removed. Allegedly, industrially painted parts cannot be stripped by alternatives. Most DCM-free products (solvent mixtures without acids or other aggressive additives) are only suitable for removing 1-component-paints and dispersion type paints (e.g. on walls). Some special products containing acids work better but are not suitable for all types of substrate (e.g. not suitable for walls) (this is based on information from a manufacturer of both DCM-based and DCM-free paint strippers).

On the other hand, companies involved in the manufacture, supply and use of alternative paint strippers argued in favour of the suitability of their products. For example:

- a manufacturer of water-borne DBE paint strippers (microemulsions) has argued "*During our 20+ years of running a furniture stripping business, 9 out of every 10 door stripping orders had at least one door started to be stripped with a conventional stripper* (i.e. DCM-based) *- only to give up when they reached the water-based base coats.* (Our product) *removes both alkyd (oil-based) and water-based/water-borne finishes*". The company has provided photographic evidence to support these claims. The company also argued "*it is quite correct (...) that alkyd paints are the most common - and therefore if our product did not work on these paints - we would not be in business and the product would not have come out of the laboratory*"; and

- a manufacturer of both DCM-based and DCM-free formulations has suggested that N'N-dimethylacetamide-based paint strippers (this solvent is related to dimethylformamide) can successfully be used for the removal of water and powder-coatings from sensitive surfaces (such as musical instruments); however, they require a strip tank temperature above 30°C, very strong air exhausting devices (odours may not be dangerous but are extremely unpleasant like rotten flesh which make this alternative very unattractive, although it can perform very well).

Views of Trade Associations and Trade Unions

<u>Danish Paintmakers' Association</u>

The Danish Paintmakers' Association are representing the major paint manufacturers and importers in Denmark and for about 15 years ago they have agreed not to supply dichloromethane based paint strippers (Danish Paintmakers' Association, 2007).

The Association in a letter to the European Commission dated 8 March 2002, notes "*The industry recognises that paint strippers containing dichloromethane are the most effective ones, but the products' use-value* ***is not proportional to the risk involved by the use of these products*** *and consequently since 1993 the industry has been asking the Danish authorities to take measures against the ongoing use of the products*".

We contacted the Association during the course of this study. The association confirmed the contents of the 2002 letter and argued that substitution of DCM is a question of "duty of care" (Danish Paintmakers' Association, 2007).

To the Association's understanding there are no particular applications for which alternatives to DCM-based paint strippers do not exist or perform particularly worse than DCM-based paint strippers. This assertion is based on the fact that the majority of professional use of DCM in Denmark requires approval from the authorities and according to the authorities no approval has been granted so far. The Association supports a total restriction (ban) on the marketing and use of DCM-based paint strippers, as opposed to imposing requirements of use of appropriate PPE or provision of appropriate information because DCM is Carc. Cat. 3 substance and is used in large concentrations in paint strippers – this in the Association's opinion is not a favourable combination (Danish Paintmakers' Association, 2007).

Finally, the Association does not believe that the applications of DCM-based paint strippers may differ between different countries, therefore, the fact that suitable alternatives are available to Danish professional users should apply to users elsewhere in the EU (Danish Paintmakers' Association, 2007).

<u>Fachverband der Chemischen Industrie Österreichs (FCIO – Austrian Chemical Industry Association)</u>

According to the Fachverband der Chemischen Industrie Österreichs (2006), the main reason for the restriction on DCM-based paint strippers in Austria was a drive to reduce ozone depletion by regulating the use and emissions of VOCs.

The Fachverband der Chemischen Industrie Österreichs believes that the fact, that DCM was banned only in Austria, and not in other Member States caused problems for the Austrian industry which also faced problems with illegal imports of such products. This, in their opinion, caused a distortion in competition (Fachverband der Chemischen Industrie Österreichs, 2006). Furthermore, the Association believes that most of the alternatives have a worst performance than DCM-based paint strippers (Fachverband der Chemischen Industrie Österreichs, 2006).

Notably, at the Paint Stripping Forum of November 2005, it was suggested that some Austrian contractors formulate their own stripping preparations using DCM (CEFIC, 2005)

<u>Danish Painters' Union</u>

In 2004, as part of the European Health and Safety Week "Building in Safety", the Danish Painters' Union held an experts' conference on organic solvents and water based paints. Participating were some 40 representatives of trade unions from 10 European countries (Denmark, Norway, Sweden, Finland, Estonia, Lithuania, Germany, Austria, the Netherlands and Belgium), the Nordic Federation of Building and Wood Workers (NFBWW) and the European Federation of Building and Wood Workers (EFBWW). Also participating were a Member of the European Parliament and representatives of research institutions and governments (BAT, 2004).

The aim of the conference was to (BAT, 2004):

- make an appraisal of the discussion on organic solvents within the trade of painting;
- exchange experiences on occupational health; and
- assess the need of European regulation on the protection of workers being exposed to organic solvents.

The Declaration of the conference states that "*the use of particular hazardous chemical substances (e.g. dichloromethane) in paints, strippers and products for floor treatment shall be banned, for instance by including such substances to the Chemical Agent Directive annex III, or the directive relating to restrictions on the marketing and use of certain dangerous substances and preparations (76/769/EEC, expected to be part of REACH) or as an extension of the Deco Paint Directive*" (BAT, 2004).

Apart from these views, it is important to consider what work has been undertaken in recent years with regard to the technical suitability of paint strippers. The following paragraphs outline the findings of these research activities.

5.13.2 Studies on the Availability and Suitability of Alternative Paint Strippers

Work for the Development of the German Technical Guidance Document TRGS 612

The wording of the German TRGS 612 (BMAS, 2006) is as follows:

"***§4.1 Substitute substances (methylene chloride-free paint strippers)***

(1) Generally speaking, suitable, effective, DCM-free paint strippers can be obtained (and readily used from a technical viewpoint) for all coatings that are removable with methylene chloride DCM-based strippers. A list of methylene chloride DCM-free paint strippers can be downloaded from www.gisbau.de.

(2) Employers must carry out tests to determine which substitute substance will be most effective in each individual case. If such tests fail (at least 3 stripping trials with potentially suitable substitute substances), then the use of substitute substances may be deemed technically unsuitable. Manufacturers or dealers can be asked for information on suitable products. The result of the tests should be documented in the risk assessment".

It is of interest that the previous version of the TRGS 612 included exceptions to allow for the use of DCM-based paint strippers) for the removal of polyvinylidene fluoride (PVDF) coatings, powder coatings and stove enamels. Testing was undertaken in Germany in January 2005 to confirm whether these exceptions were appropriate. Thirteen different paint strippers were tested on 2-component epoxy coatings and thermal cure (coil enamel and powder coatings); testing was not undertaken on:

- dispersion paints,
- oil paints,
- alkyd resin lacquers,
- latex paint, and
- polyurethane lacquers,

as these were agreed by all parties to be able to be removed by DCM-free paint stripping formulations. The results of the testing are shown in Table 5.13 and indicate that every coating that could be removed with a DCM-based paint stripper could also be removed using a DCM-free paint stripper (Rühl, 2005).

Table 5.13: Effectiveness of Alternative Paint Stripper Systems in Removing Specific Coatings (test results for the TRGS 612 Technical Rule)

Coating type	DCM-free products	DCM-based products
2-component epoxy		
Disboxid	-	-
Disboxid	+	-
Sikafloor 2530	+	+
Sikafloor 261	+	+
Thermal cure (coil, enamel, powder)		

Table 5.13: Effectiveness of Alternative Paint Stripper Systems in Removing Specific Coatings (test results for the TRGS 612 Technical Rule)		
Coating type	**DCM-free products**	**DCM-based products**
PVDF	-	-
Colorcoat HPS 200	+	-
Polyester	-	-
Interpon	+	+
Plastophen H-S	+	+
Source: Rühl, 2005 *Details of testing:* *- 13 different paint strippers (2 DCM-based paint strippers and 11 DCM-free paint strippers);* *- 22 different coating types on metal sheets;* *- application on 24 January 2005 / 15:00 – 17:00;* *- inspection on 25 January at 9:30 am; and* *- room temperature ranges: day 8-9°C and night: 5°C*		

It should be noted that the Working Group responsible for the development of the TRGS includes representatives of decorator associations, trade unions, manufacturers of paint strippers (with and without DCM), producers of DCM and other solvents and others and the results of the assessment of effectiveness of different paint stripping products was collectively agreed upon.

Findings of a Study by Miljøstyrelsen (Danish EPA)

The study was intended to form the basis of initiatives designed to restrict or ban the use of DCM in Denmark and would assist in providing targeted information to consumers and those involved in professional uses of DCM-based paint strippers. The summary of this project (MST, 2002) suggests that the available alternative chemicals and methods that, when used in combination, allow for successful substitution of DCM-based paint strippers.

"*In continuation of a voluntary agreement between the Danish EPA and the Danish Paint, Varnish and Lacquer Industry Association (FDLF), substitution of hazardous substances is automatic, in principle, but DCM is still being used in paint/lacquer removal products*[41]*. The purpose of this project was to clarify the extent to which DCM and other environmentally and health-hazardous substances in paint/lacquer removers can be replaced with substances less detrimental to health and the environment or by other, non-chemical methods. The conclusions are summarised as follows:*

"*Based on the studies in the project, the following conclusions can be drawn with regard to paint/lacquer removers:*

41 It is worth noting the existing national legislation in Denmark, a Member State which has extended the implementation of the Carcinogens Directive to Carc. Cat. 3 substances , such as DCM – see the discussion in Annex B to this report.

- *none of the paint/lacquer removal methods investigated – chemical or mechanical – involves the same adverse effect on both health and the environment as the use of DCM. Moreover, paint/lacquer removers can often be avoided entirely if the paint or lacquer is firmly fixed;*

- *for the vast majority of applications there are chemical DCM-free products which are sufficiently effective. On the basis of present knowledge, there are chemical substitutes with acceptable effects on health and the environment in relation to DCM. In graffiti removers, for example, the active substances used can in all likelihood be used to remove traditional paint and lacquer;*

- *the mechanical methods are associated with adverse effects on health…it can be concluded that inappropriate use of such methods can result in serious effects. Used appropriately, however, such mechanical methods can enhance the quality of environmental and health factors in a paint and lacquer removal context as compared with the use of DCM; and*

- *in the judgement of the industry, various combinations of mechanical and chemical methods for removing paint and lacquer will be capable of replacing paint/lacquer removers containing DCM.*"

Opinion of the French Institut National de Recherche et de Sécurité (INRS, 2006)

The French Institut National de Recherche et de Sécurité (INRS) issued on 21 August 2006 a factsheet for the "facilitation of substitution of DCM" in façade cleaning/graffiti removal operations. The contents of the fact sheet – prepared by a group of engineering consultants, safety inspectors and medical consultants and subject to update if new toxicological knowledge and techniques emerge - are as follows:

"*DCM is used for its solvent properties and its rapid evaporation. Other products or other processes can also be considered. Substitute chemical products include:*

- *solvents that 'soften' the paint, and do not containing either chlorines, or any product classified as toxic*;

- *formulations containing derivatives of 1,3-dioxolane-2-one, such as ethylene carbonate (CAS No 96-49-1), propylene carbonate (108-32-7), glycerol carbonates, etc… These products are generally have a very low volatility and are non-flammable in ambient temperature has*; and

- *strongly alkaline aqueous products, depending on the type of painting to be stripped*.

Possible alternative paint stripping processes include:

- ***stripping with ice granules or CO_2****: be aware of the risk of anoxia when using CO_2 in confined or poorly ventilated surroundings;*

- ***sanding and other high pressure blasting**: sanding, or high pressure blasting with any material except silica and 'plastics' can be used. Please note that the use of high-pressure tools does expose upper limbs to the risk of musculoskeletal risks and are very noisy. Be aware that protection is needed against the blasting medium but also against inhalation of dust from paint strippers and the substrate; and*

- ***laser stripping**: there are certain risks associated with this process*".

Testing of Paint Strippers undertaken on behalf of EASCR

Background

In December 2004, the European Association for Safer Coatings Removal (EASCR) organised testing of a number of different paint stripping products based on DCM, NMP, DMSO, benzyl alcohol and DBEs. As the results report states, "*one important aim was to understand which solvents are used in the leading alternative strippers available in the market place and why their sales are so poor in relation to DCM strippers*." The questions that were to be answered included:

- are alternative paint strippers less effective than DCM strippers?
- are some alternative solvents better than others?
- what are the strengths of DCM?

Samples and Substrates

Twelve samples were collected throughout the UK and Europe to be included in the tests. Some were purchased or supplied by distributors; others were donated directly by paint stripper manufacturers and EASCR members to enable their product to be included in the testing. The samples included the following (EASCR, 2004):

- Sample 1: Contained DBE;
- Sample 2: Contained DBE (EASCR Member);
- Sample 3: Contained DBE;
- Sample 4: Contained DBE/NMP (EASCR Member);
- Sample 5: Contained DBE/NMP (EASCR Member);
- Sample 6: DMSO /Acetone/ Butyl Acetate (EASCR Member);
- Sample 7: Contained DBE/Naphtha (EASCR Member);
- Sample 8: Contained DBE (EASCR Member);
- Sample 9: Contained DBE/NMP (EASCR Member);
- Sample 10: Contained DBE/Benzyl Alcohol (EASCR Member);
- Sample 11: DCM (the largest selling DCM stripper available in UK); and
- Sample 12: NMP.

Different combinations of substrates and coatings were identified for testing purposes. Some of the tests were carried out in the labs with the substrate laid horizontal whilst others were conducted outside on vertical surfaces. The substrate/coating combination and location of test were (EASCR, 2004):

- ***wood/alkyd***: this was an old door from a building under renovation. It was painted with a lead primer, an undercoat and an orange coloured topcoat. The paint was estimated to be 30 to 40 years old. The door was tested in the labs and laid horizontally during the entire experiment;

- ***plaster/acrylic***: trial conducted on a wall located in an internal doorway. The surface of the wall was covered with gypsum plaster. It was painted with approximately 75-100 microns of vinyl silk emulsion paint (2 coats). The paint was in good condition and had been applied within the last 4 years;

- ***metal/epoxy & polyurethane mix***: two external steel posts were worked on during this test. The paint stripper was applied to an area of the post that was quite sheltered from the sun, wind and rain. The post had 6 coats of thick paint (500 microns). It was made up of epoxy primers and undercoats with a polyurethane topcoat. This topcoat was applied 5 years ago; and

- ***metal/alkyd***: this was an old metal panel, which had been salvaged during some recent renovation work. The panel was taken to the lab for testing and remained horizontal during all the tests. It had 5 layers of paint in total, a primer then a combination of undercoat and gloss (150 microns paint). The initial coats were applied 30-40 years ago, with the final coat painted during the last 10 years. Apart from the primer, all the coats of paint were white or cream, making the scoring very difficult, unless the sample had removed all the paint down to the green primer.

Each product was tested using 3 time measurements:

- 1 hour;
- 4 hours; and
- 18 hours.

Results

The scores were decided collectively by the team and recorded in an Analytic Hierarchy Process (AHP). The scoring was subjective and the team had to mark each sample based on how much "better" each stripper was compared individually to each of the others. The
definition of "better stripper" is one which removes more paint than another in the period stated. The following AHP key was used to score each stripper against another:

- 9 - Extremely Better
- 8
- 7 - Very Strongly Better
- 6
- 5 - Strongly better
- 4
- 3 - Moderately Better
- 2
- 1 - Same

If a sample was considered to be "better" than another then a number from the key was selected to represent how much better it was. If a sample was deemed to be worse than its comparison then it was entered into the AHP as one over the number, e.g. 1/7.

Overall results: the most successful paint stripper over all the tests and time durations was Sample 7 (DBE/naphtha). The runner up was Sample 9 (DBE/NMP), which was faster acting than Sample 7 but proved not to be so effective over the longer tests. Both Samples 5 (DBE/NMP) and 6 (DMSO) did well in the tests. Sample 6 gave good results over the shorter periods, whereas the effectiveness of Sample 5 increased with higher time durations. Samples 1 (DBE), 3 (DBE) and 12 (NMP) proved to be ineffective throughout the testing. Figures 5.1 and 5.2 are reproduced from the EASCR report and show graphically how each sample fared.

For each product the following remarks are made in the EASCR (2004) report:

1. ***Sample 7 (DBE/naphtha)***: combining all the test scores this stripper proved the be the top performer of all the paint strippers tested and only slipped out of the top 4 positions on one occasion – after 4 hours. The longer it was left on the surface the more paint it would remove. This is a very versatile stripper that worked effectively on all surfaces and coatings.

2. ***Sample 9 (DBE/NMP)***: its best performance was on wood (alkyd paint) were it finished either 1st or 2nd over the various durations. Its ranking did decrease slightly when applied for longer periods.

3. ***Sample 5 (DBE/NMP)***: rankings improve sharply when left for more than one hour. Results were quite poor on wood (no matter how long the product was left), but were excellent on acrylic paint.

4. ***Sample 6 (DMSO/Acetone/Butyl Acetate)***: this appears to be a better performer over shorter periods as it came top overall in the 1 hour tests but had no top 4 performances in tests over 18 hours. The product came 4th overall but was ineffective on acrylic paint;

5. ***Sample 10 (DBE/NMP)***: this product was a speedy performer on wood. Its position increased greatly on plaster when left for 18 hours.

6. ***Sample 8 (DBE)***: when tested on vertical surfaces this product had a tendency to run. In most cases the longer you left the product on the higher up the rankings it went.

7. ***Sample 11 (DCM)***: this product only made it into the top 4 when tested over 1 hour. It did not remove any acrylic paint from plaster. Over 1 hour it was 2nd on metal but was only average (6th) on wood.

8. ***Sample 4 (DBE/NMP)***: rankings improved in the when left on for 18 hours. It was a below average performer with its best results coming from the acrylic/plaster test.

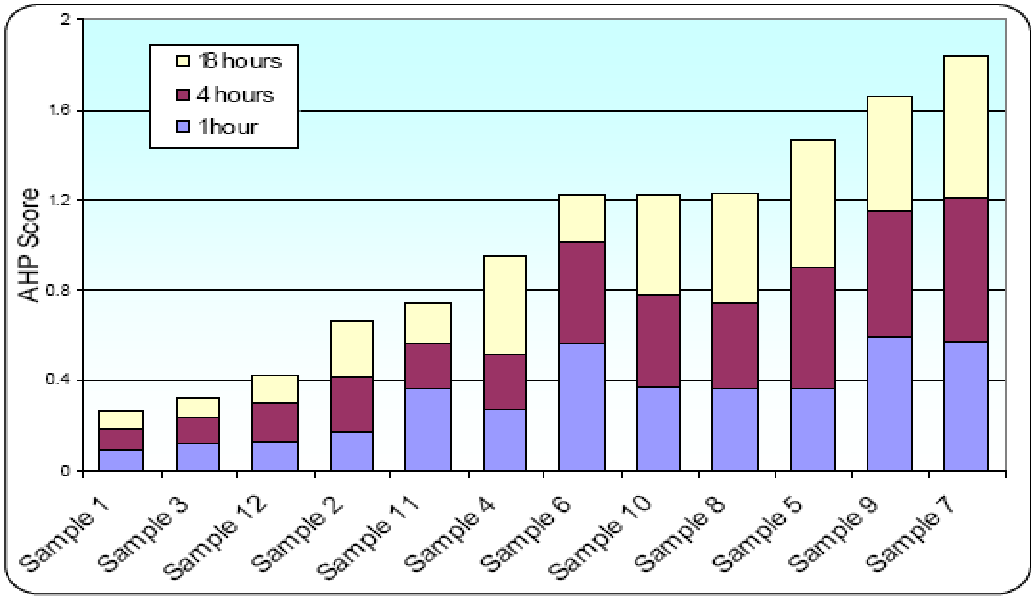

Figure 5.1: Overall Performance of Paint Strippers in the 2004 EASCR Testing

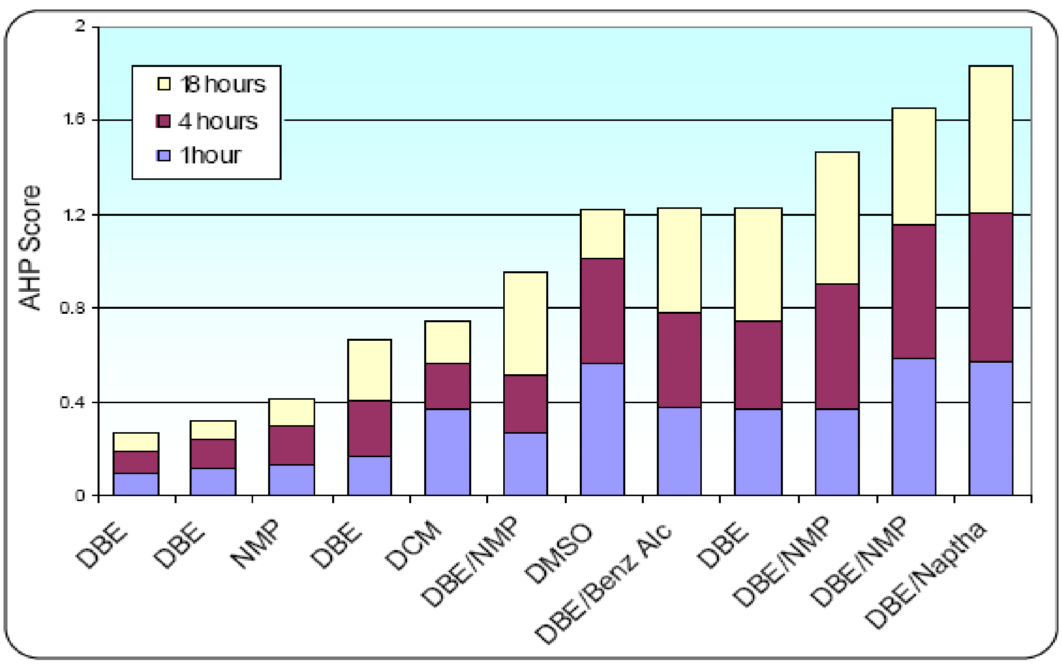

Figure 5.2: Overall Performance of Paint Strippers in the 2004 EASCR Testing - Composition Performance

9. ***Sample 2 (DBE)***: during the test sample 2 got into the top 4 on two occasions. Once after a 4 hour performance and another after 18 hours. It performed reasonably on metal and excelled on wood over 18 hours.

10. ***Sample 12 (NMP)***: performed poorly across all coatings. Its best performance was on acrylic paint were it came in 7th over 18 hours.

11. ***Sample 3 (DBE)***: proved to be a very poor product during the tests. Tested on metal and wood with alkyd and epoxy coatings it failed to remove even the tiniest amount of paint. It had modest success when applied to plaster coated with acrylic paint. No details with this stripper, because of the results.

12. ***Sample 1 (DBE)***: this product performed very poorly over all the tests. It was constantly 11th and 12th in the rankings. The company was reluctant to supply a sample for testing. As it did not remove any paint in any of the tests it was suspected of being a fake sample. Upon investigation of its poor performance it was found to be a graffiti remover and not a paint stripper.

The results over time were as follows (EASCR, 2004):

- ***over 1 hour***: Sample 6 (DMSO) accumulated the most points during all the tests over 1 hour; it was particularly effective on metal surfaces but not so good on plaster/acrylic. Samples 7 (DBE/naphtha) and 9 (DBE/NMP) were significantly better performers on wood than any other product and Sample 7 was the only product to be consistently in the top 4 over all the tests. The DCM paint stripper (Sample 11) overall position would have been increased slightly if plaster/acrylic had been excluded, as this product had no effect at all on the acrylic paint;

- ***over 4 hours***: although Sample 9 (DBE/NMP) performed consistently well over the tests, always in the top three, it still finished behind Sample 7 (DBE/naphtha). Sample 7 came a disappointing 5th on wood (particularly after its impressive score after 1 hour), but still managed to score higher in the other tests to make it the overall winner. Sample 5 (DBE/NMP) scored extremely highly on the epoxy mix paint but was only average on combinations of wood & metal with alkyd paint. Sample 6 (DMSO) actually was top scorer on the wood surface but its low scores in plaster/acrylic and metal/alkyd reduced its overall position to 4th; and

- ***over 18 hours***: Sample 7 (DBE/naphtha) was again the top performer only this time by a bigger margin than in the 4- hour tests. Sample 5 (DBE/NMP) was once more runner up with an impressive performance on plaster/acrylic but a poor display on wood/alkyd. Sample 2 (DBE) overall positions seem to be directly related to time, the product seems to be more efficient with greater time. Whilst Sample 12 (NMP), which would be expected to give an increased performance with increased time, remains 10th as it has throughout all the test durations.

According to EASCR's conclusions, the testing successfully proved that alternative paint strippers can be effective, fast acting and very versatile. Sample 7 (DBE/naphtha), the overall winner, is formulated using a very high percentage of DBE. It is visible from the results that the DCM and DMSO paint strippers are particularly fast reacting and this can be endorsed by the physical bubbling evident early in the testing for both these solvents. Even so, over an hour, the three top performers were alternatives (2 DBE and 1 DMSO) (EASCR, 2004).

5.13.3 Availability of Alternatives for Selected Applications/Sectors

Alternatives and Methods for Graffiti Removal

Information on graffiti removal techniques is provided in InfoMil (2002); this is the document underpinning the covenant between the authorities and representatives of the cleaning sector in the Netherlands. The following paragraphs, unless explicitly indicated, they are taken from the InfoMil document.

Alternative Formulations

In the practice of graffiti removal, the source/components of the graffiti are hardly ever known and often the object is covered with various types of graffiti. Therefore, the method for removal of graffiti will be determined by establishing the type of surface and then to establish how this surface has been treated.

For graffiti removal, there is a wide variety of all kind of solvent and water-based products as well as blasting with several types of granulate (Bunnik-Advies, 2007a). Non-VOC containing alternatives (for instance, based on DBEs) evaporate less quickly than DCM and have, therefore, apparently lower adverse environmental and health effects (InfoMil, 2002).

Experts suggest that, in general, alternatives may give a more or less good result. However, especially for some specific kinds of paint materials, such as two-component reactive types, alternatives may not remove the graffiti sufficiently well (Bunnik-Advies, 2007a). InfoMil (2002) agrees that, in many cases, there are no appropriate alternatives for organic solvents in the removal of graffiti.

Graffiti removal products based on non-DCM solvents generally take longer to work. In comparison, to DCM-based formulations that may take between 20 minutes and 1 hour, when using DBEs 8-24 hours may be needed before the graffiti can be removed (InfoMil, 2002).

In addition, this longer absorption time has also as effect that more of the solvent will evaporate which affects the end result – it takes longer to remove the graffiti and it is more labour intensive, and special measures need to be taken to prevent exposure of third parties (passers-by and children playing nearby).

Blasting, with several types of granulate, as an alternative has a much higher risk of damaging the surface of the material where the graffiti is applied. This is particularly the case where repeated blasting takes place (Bunnik-Advies, 2007a).

InfoMil (2002) notes that, because of the adverse environmental and health effects of DCM and other halogenated solvents, the use of alternatives is preferable, if there are no practical obstacles for using them, over the use of the usual VOC-containing solvents. However, a Dutch expert has confirmed that DCM-based graffiti removing products still find wide use in the Netherlands (Bunnik-Advies, 2007a). InfoMil (2002) also advises users to opt for using gels instead of liquid solvents. Gels as a solvent has the advantage that it evaporates less quickly. It seems that gels also absorb the contamination. Liquid solvents have the tendency to be absorbed into the surface that needs to be cleaned and in due time this will again be released in the air. Graffiti in the meantime will have penetrated more deeply into the surface and will hardly be possible to remove. When using gels, it is important to dry scrape, collect and dispose of the solid waste after which the surface can be rinsed with water that can be released into the drainage.

When the use of solvent-based cleaning products cannot be avoided, measures to reduce their adverse effects should be taken. In the graffiti removal process, waste products including contaminated water (effluent) need to be disposed of in an environmentally safe way avoiding unnecessary contamination of soil and water (InfoMil, 2002).

Removal of Graffiti from Untreated Mineral Surfaces

Facades and walls are often covered with graffiti. Mostly these are brick-like materials such as cement work, concrete, stone or plaster. Art objects often fall in this category as well. Untreated these mineral surfaces are often porous resulting in the graffiti penetrating deeper, depending on the method of application, into the surface which makes it more difficult to remove.

Removal with thin liquid solvents often has an adverse effect because some of the graffiti dissolves and subsequently deeper penetrates into the surface. Unprofessional cleaning could result in using more solvents to clean up the results without the graffiti being removed completely. Then, solvents that are more aggressive need to be used to achieve the desired result.

A better method is to use gel, which contains the same solvents (see discussion on gels above). However, in some cases, the gel will not absorb some components of the graffiti and other components may have penetrated too deep into the surface. In some situations the use of a paint stripper/remover based on DCM could be considered.

In practice, however, all the above-mentioned methods may not remove the graffiti completely. After several attempts with various products and methods, often users resort to applying aggressive use of high-pressure wash/sand blasters or etching to get the desired result. With these methods, a thin surface layer will be removed. It is apparent that with regular use of blasting methods some surfaces will be substantially damaged.

Removal of Graffiti from Painted Surfaces

Graffiti removal of painted surfaces appears in practice nearly impossible to achieve without leaving traces. Because of the presence of solvents in the graffiti-paint, in many cases, the painted surface will be damaged due to both paint types being mixed. When this occurs, it is not possible to remove graffiti even when using the most effective solvents. To avoid unnecessary waste of solvent and the associated pollution issues, InfoMil (2002) advises against the use of solvent-based graffiti removers. InfoMil argues that the only possibility is to re-paint the object making sure that it covers the graffiti properly.

Only in exceptional cases graffiti should be removed with cleaning substances or solvents that do not damage the existing paint layer such as water-based cleaning products.

Removal of Graffiti from Smooth Non-porous Materials

Smooth and non-porous materials, such as metal and glass, can in many cases be treated successfully without causing any damage. This can easily be done with organic solvent-based products, although with a bit more effort this can also be done with water-based cleaning products. The extra effort can easily be justified in the interest of the protection of the environment and public health. InfoMil (2002) encourages users to try the latter method first and, after establishing that this does not work, to use organic or halogenated solvent-based products while taking care of releases to the environment.

Removal of Graffiti from Anti-graffiti Systems

Manufacturers of anti-graffiti systems indicate on the product which cleaning products or methods should be applied when necessary. If applied inappropriately, damage to the anti-graffiti system may occur in which case the work will have to be repeated or a replacement anti-graffiti system put in place. This will have both cost and environmental implications and, therefore, careful assessment and planning is recommended.

Removal of Graffiti from Permanent Anti-graffiti Systems

Permanent anti-graffiti systems have been developed to make it easy to remove graffiti using the smallest possible quantity of cleaning products. Applying the method recommended by the supplier of the anti-graffiti system should result in very thorough removal. One of the aims of graffiti use is to make it difficult to remove and manufacturers of permanent anti-graffiti systems are constantly looking at product improvements to keep one step ahead. Most anti-graffiti systems, which at present are available on the market, must be cleaned with solvent-based cleaning products, which may result in considerable releases of VOCs. There are, however, anti-graffiti systems available that contain less hazardous substances, but the application of these is not necessarily problem-free. Each situation will differ and professional help may be needed to deliver quality results.

Removal of Graffiti from Temporary Anti-graffiti Systems

With the removal of graffiti from these systems, the whole protective layer will be removed including the graffiti. Most systems can be cleaned with water-based products but in some cases a solvent-based product may need to be used. Again, water-based products are preferable since they are less damaging for the environment and public health; in any case, the necessary precautions need to be taken into account prevent waste ending up into the sewer.

Removal of Graffiti from Semi-permanent Anti-graffiti Systems

With these so-called multi-layer systems the top layer is temporary and can be compared to temporary systems above. Most of these systems can be cleaned with water. With the single layer systems part of the anti-graffiti system will be removed and will then need to be replaced after cleaning.

Removal of Posters

In places where frequently posters or other material is placed, sometimes thick layers of glue accumulate and at some point this needs to be removed. A usual method, but generally undesirable, is to use high-pressure wash with warm water. The glue part will be dissolved and removed in fragments from the wall. The resulting dregs will subsequently be disposed of in the sewer using large quantities of water. This is not ideal since this material can cause blockages in the sewer and water pumps in the wastewater treatment plants.

The poster material needs to be removed as much as possible so that it can be disposed of as solid waste. With this method the user can use high pressure but only to remove the poster material and glue from the wall but not to dispose it into the sewer.

Removal of Posters on Anti-graffiti Systems

Some anti-graffiti systems prevent the placing of posters on them due to the presence of a wax layer or anti-adhesive materials. Consequently, removing the posters from these systems is relatively easy and it is possible to remove them with use of little or no water. Use of solvent-based cleaning products should be avoided.

Alternatives for Conservation and Restoration Work

We have received communication from a number of (UK) companies involved in conservation and restoration work using DCM-based paint strippers. These companies have suggested that DCM-based paint strippers are the products of choice for a number of reasons such as:

- removing old coatings from building facades without causing damage to the fabric of the façade would be difficult with alternatives;

- some alternatives will work in some circumstances. The only consistent performers are the DCM-based products;

- alternatives to DCM tend to be more expensive (usually about 50-80% more) - except caustic based chemicals which are the same price or slightly cheaper;

- all caustic chemicals have the disadvantage of having to be left for at least 12 hours (usually 24) which means at least two site visits etc.;

- the labour required to apply caustic poultices is twice as much as when using paste products (e.g. DCM-based products) as the poultices are plaster like in consistency and have to be trowelled on like render rather than brush applied. One team of three men will coat up about 15-20 square metres a day with caustic poultice, whereas the same team could completely strip 15 metres using DCM products in one day;

- the alternatives have to be trialled on every occasion to see if they will remove specific coatings. Generally the DCM-based products will remove any coating encountered;

- caustic products can cause chemical imbalances in some substrate as mentioned above. It has been mentioned that many English Heritage surveyors will specifically forbid the use of caustic-based products for this reason; and

- the companies may treat all chemicals the same and wear the same protective clothing. Therefore, the use of alternative paint strippers does not make operations less complicated or less costly[42] (however, this does not mean in any way that users currently use the correct PPE equipment when handling DCM-based products).

We have contacted the Society for the Protection of Ancient Buildings (SPAB) and the Committee of the Traditional Paint Forum (TPF)[43] located in the UK to enquire on the importance of DCM-based paint strippers in conservation and restoration work. We were advised that both SPAB and TPF support the general move towards reducing the use of DCM in paint strippers, where viable, but the practical experience of these organisations shows that this is frequently not always possible because of the lack of suitable alternative products. For example, non-DCM gels are often employed to remove paint but it can be difficult to achieve good results if the weather is too hot or too cold. The SPAB argued that any attempt to totally restrict the use of DCM-based paint strippers at

[42] This argument has been made for the use of PPE in graffiti removal operations.

[43] The Society is an educational, advisory and campaigning voluntary organisation and it is notified of listed building applications for demolition in England and Wales. The Society provides a free technical advice line and issues advisory publications. The Society has just fewer than 9,000 members; they comprise leading historic building professionals, whose cumulative expertise is given voluntarily to the Society, as well as homeowners, and those who support the cause. The SPAB is independent of Government and funded primarily by private subscription. The TPF came into being in 1994. Its aims and objectives are to debate and encourage the development of understanding and appreciation of traditional paint. The membership is broad and includes conservators, architects/surveyors, specialist contractors, suppliers and others. They provide its only funds (SPAB, 2007b).

this stage, therefore, could have a detrimental effect on conservation work to many of the UK's historic buildings (SPAB, 2007a).

We enquired on whether the UK has any particular differences compared to other EU Member States with regard to the types of conservation and restoration work undertaken in the country. We pointed out that conservation and restoration work surely is undertaken in countries like Austria, Denmark and Sweden where the use of DCM-based paint strippers is restricted. The representative of SPAB suggested that he had little experience of work in the other countries; therefore he was unable to comment on this particular aspect (SPAB, 2007b).

Consultation with English Heritage[44] did not confirm the aforementioned assertions on the importance of DCM-based paint strippers. A maintenance manager for the organisation noted that he very rarely has use for stripping paint for several reasons; one of the main reasons is the destroying of any historical paint under the top surface. With regard to graffiti, this manager recently had to remove graffiti from surfaces like flint, lime mortar and concrete but in all cases the method used was a high-pressure water hose with a granite abrasive. Our consultee emphasised that he had never personally used any chemical paint strippers in his maintenance work (English Heritage, 2007). It is possible, however, that other operations overseen by English Heritage may require the use of chemical paint strippers.

Finally, a UK company involved in the conservation of historic metal objects has advised us that the range of chemicals used by its employees include DCM-based paint strippers, caustic products and water-based DBE products. These are used for the removal of paint from various substrates.

The company emphasised the ability of DCM-based paint strippers to effectively remove paint quickly. The company sometimes work under tight time constraints. If it is necessary to remove all the paint from an object in a few hours, they can use several applications of a known DCM-based paint stripper without having to wait long for each application to work. However, an immediate result is not necessarily a better result – it is merely quicker. The company does not envisage and major problems from a potential restriction on DCM-based paint strippers, although it has pointed out that other solvents may also be hazardous.

Overall, DCM-based paint strippers may find applications in conservation and restoration work and may deliver good results within a short timeframe. However, it is certain that conservation and restoration work as well as graffiti removal is undertaken in the Member States that have already placed restrictions on DCM-based paint strippers. Companies in these countries obviously do not use DCM-based products. To our knowledge, there have not been any problems in these types of operations in these countries neither has any consultee offered a reasonable explanation why replacement of DCM-based products in these few countries may have been easier. This leads us to

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44 A UK government body with a broad remit of managing the historic environment of England which had been suggested as being involved in the choice of chemicals to be used on historical buildings.

assume that conservation and restoration work as well as graffiti removal can, in principle, be undertaken by other means or using different chemical formulations.

Alternatives for the Automotive and Rail Industry Sectors

We have received information on two case studies for the aforementioned sectors.

<u>Case Study 1: Replacement of DCM-based Paint Strippers by a Large Automotive Manufacturer</u>

Confidential information has been received by a large automotive manufacturer regarding the use of DCM-based paint strippers in the vehicle repair industry. The manufacturer has suggested that DCM-based products have been banned from use by the company's employees on site in 2005 as part of company standards and this affects two sites in the country of location. Other European sites of this company also follow this company standard and do not use DCM-based products.

The manufacturer has advised that alternative chemical paint strippers have been successfully trialled and the preferred choice for paint stripping are currently these alternative paint softening chemical products combined with mechanical stripping or scouring. The company does not also expect any adverse (economic) impact from the switch to alternatives.

<u>Case Study 2: Replacement of DCM-based Paint Strippers in the Automotive and Rail Industry</u>

As discussed in Section 2.3.1, information has been received from a company running eight branches across the UK that use DCM-based products for paint stripping and carbonised oil removal. For paint stripping the product is used in a vat containing between 200-400 litres with a water vapour barrier. This paint stripping activity is mainly applicable to aluminium casings from rail applications. The product is also occasionally used as a brush applied paint stripper on radiator housings (mainly commercial vehicle radiators).

Use as a carbonised oil remover is normally achieved by either dipping the item to be cleaned in a vat containing DCM or by pumping the DCM formulation through the unit and then flushing with steam cleaners.

The company has decided to reduce the perceived health and environmental risks by completely removing the DCM-product from these business applications. The company is currently embarking on a trial at one site where DCM- based product is being tested and compared with a new, non-DCM product.

The company also noted that it sells DCM-based paint stripper in 500ml tins to the UK automotive market. The company is of the opinion that the use of this product is occasional in most vehicle repair applications, due to falling incidence of original panel repairs.

Alternatives for the Aerospace Industry Sector

As shown in Section 2.3.1, DCM-based paint strippers are suggested to find limited use in the aerospace sector; it has been estimated that DCM-based paint strippers represent around 25% of the paint stripper market in Europe; 65% of the market is taken by benzyl alcohol/formic acid formulations; the remainder is taken by alkaline strippers, peroxide strippers, etc. In the recent seven or so years the use of hydrogen peroxide/benzyl alcohol products has increased significantly.

5.13.4 Human Health and Environmental Hazards of Alternatives

The alternative paint strippers contain a large number of chemical components. These components may have a very diverse hazard profile. Annex B includes a table of components that may be found in alternative products available on the German market. This shows that the majority of them are classified under Annex I to Directive 67/548/EEC. Depending on their concentration in the formulation, they could pose hazards to the user. The same, however, applies to the components of DCM-based paint strippers. Within the agreed scope of the study, it was only possible to focus on a certain number of chemical substances that are the key components of alternative formulations. These substances have been assessed for their hazards to human health and the environment earlier in this Section. These substances do not come with issues of their own such:

- ability to harm if inhaled or swallowed (benzyl alcohol);
- flammability (1,3-dioxolane);
- corrosivity (sodium hydroxide);
- skin and/or eye irritancy (DBEs, DMSO, benzyl alcohol, 1,3-dioxolane, sodium hydroxide – some of them slightly irritating);
- sensitisation (benzyl alcohol);
- skin absorption issues (NMP and DMSO);
- genotoxicity concerns (DMSO) and reprotoxicity concerns (NMP and 1,3-dioxolane); and
- resistance to biodegradation (1,3-dioxolane).

Some of the selected alternatives are marginally more toxic to the aquatic environment; however, they do not appear to pose a significant risk. At the same time, DCM is on the list of Priority Substances under the Water Framework Directive.

DBEs and DMSO appear to be the only substances without a classification and labelling requirement at present. All of the chosen alternative substances are considerably less volatile compared with DCM (with 1,3-dioxolane is the most volatile among the substitutes). At the same time, NMP appears to pose more significant risks than DCM due to its properties as a Repr. Cat. 2 substance. The TRGS 612 advises against the use of paint strippers based on either NMP and DMSO since these products are very readily absorbed into the body through the skin and also aid skin resorption of substances such as polycyclic aromatic hydrocarbons (PAHs) (BMAS, 2006). The same document advises against the spraying of caustic paint stripping formulations.

Overall, while each alternative has is own hazard profile, none of the above appears to combine the characteristics of DCM that are of concern i.e.

- high concentration in formulations;
- high volatility that results in high exposure levels;
- CNS effects;
- limited evidence of carcinogenic effects;
- priority substance status under the Water Framework Directive).

Moreover, it is important that even when alternative paint strippers are used, appropriate conditions of ventilation and use of appropriate PPE are very important and should not be disregarded.

5.13.5 Relative Cost of Alternative Paint Strippers

Comparison of per Unit Costs

The information received through consultation is consistent in suggesting that the alternative products based on the above selected substances are more expensive than DCM-based formulations on a per unit basis (i.e. the cost for purchasing a certain amount of the product). The Malta Standards Authority (2006) has suggested, however, that strippers containing toluene, xylene or sodium hydroxide can be cheaper than DCM-based paint strippers. Some data were made available to us through consultation and show that in October 2005, the prices for a number of products available to UK consumers were:

- NMP-based products: €20-26.4 (£13.57-17.96)/litre;
- DMSO-based product: €26.8 (£18.20)/litre;
- water-based DBE product: €25 (£16.96)/litre; and
- DCM-based product: €10.3 (£6.99)/litre.

These prices were for retail sale to consumers. When purchasing for professional or industrial uses in bulk, the prices would be considerably lower.

Other Parameters Affecting the Cost of Alternatives

When considering the relative cost of alternatives, the following parameters need to be taken into account:

- ***the number of applications of the product before the coating is removed is important***: even if a product is less costly, if it is less effective, repeated applications will increase the overall cost of using it;

- ***the time required for the paint stripper to achieve the removal of a coating is important***: while alternative solvents are less volatile than DCM so that they stay on the surface for longer, some of them may generally be less effective in removing coatings quickly; hence, the alternative formulations may invariably need to be left on the substrate for a considerable period of time before scraping off. This may indirectly increase the cost using the formulation by forcing changes to the workflow, increasing labour costs and by potentially causing idle times if actions are not planned carefully. This is discussed in more detail in Section 0 below. The box below presents another example with a comparison between DCM-based products and caustic paint strippers;

Example: Comparison of Coverage Costs for Caustic Paste and DCM-based paint strippers (Percival, 2005)	
Similarities of two systems: • a 15kg trade bucket of caustic paste costs about €70 and will remove up to 5 m^2 in a single treatment - a rate of €14 euro/m^2; and • DCM-based paint remover covers at 0.9 litre/m^2 and retails at €35 euro per 5 litres. This may require 2 applications for complete removal giving a cost of about €13/m^2.	**Differences of two systems:** • Labour for additional site days; • 24-hour protective sheeting over the paste; • prolonged equipment hire; • protection of sensitive adjoining structures; • neutralisation of surfaces; and • overnight isolation of property and relocation of residents.
The formulator argues that the relative similarity in product cost of caustic paste with DCM-based paint strippers compared to the alternative solvent-based paint removers make caustic products viable commercial alternative for retail outlets & small scale domestic DIY users. However, in his analysis, the application costs are higher than for DCM-based paint strippers. This analysis evidently does not make a reference to the changes in cost for PPE when DCM-based paint strippers are replaced by caustic alternatives.	

- ***the type of equipment that an industrial user needs to have in place before using an alternative is important***: it has been suggested that increased costs would result from the installation of new equipment (isolated tank/heating) and from the need to heat the bath during operations. A German formulator advised us that (at least in Germany) one has to ensure that your facility is explosion proof if he is working with solvents with flash points below 61°C or if he warms up flammable products, so that the bath temperature is at least 20°C lower than the flash point of the product in question;

- ***the range of products required for the range of services offered by a company***: if the user needs to remove various types of coatings then a variety of paint stripping formulations may need to be available for use. Purchasing smaller quantities of several products might be more costly than purchasing a large quantity of one paint stripping formulation;

- ***the cost of PPE and of forced ventilation (where necessary)***: the information collected thus far suggests that users (essentially the UK users that have submitted information during the course of recent months) tend to purchase equipment that is relatively inexpensive compared to what is described, for example, in the TRGS 612.

As discussed earlier in the Report, the equipment currently used by companies involved in professional uses may not be the most appropriate considering the measured levels of DCM during the use and application or DCM-based paint strippers; and

- ***future price changes for alternatives***: it is likely that if a restriction is imposed on the marketing and use of DCM-based paint strippers, the demand for alternatives will grow and this may add downward pressure to the prices of alternative DCM-free formulations.

As suggested by a manufacturer of DCM-based paint strippers who is linked to the aerospace industry, "*cost comparisons are depending on the very different regulations in European countries. In countries with high Health, Safety and Environmental requirements, costs* (from using alternatives*) are even lower and DCM is already nearly completely substituted and banned on companies' black lists*".

Influence of the Cost of PPE and Environmental Controls on the Overall Cost

Berufsgenossenschaft der Bauwirtschaft (2005) has calculated the cost of PPE for the occupational user of DCM-based paint strippers, if the provisions of the German TRGS 612 are adhered to in full. It appears that the overall cost for PPE when DCM-based paint strippers are used may be more than 30 times that of the cost of PPE that needs to be used when alternative formulations are handled.

Table 5.14: Overview of PPE Requirements for DCM-based and DCM-free Paint Strippers

Parameter	DCM-based strippers	DCM-free strippers
Eye protection	If splashing is possible: goggles	If splashing is possible: goggles
Gloves made from	Fluororubber	Polychlorprene, nitrile caoutchouc
Skin protection	Fat free /low fat content ointment	Fat free /low fat content ointment
Respiratory protection during treatment - by hand - by spraying	Self-contained respirators Self-container respirators	Filter types: A1 Filter types: A1-P2
Protective clothing during treatment and cleaning	Disposable chemical protection clothing	Disposable chemical protection clothing
Cost of one full set of PPE	Approx. 2,750 Euros	Approx. 85 Euros

Source: Berufsgenossenschaft der Bauwirtschaft, 2005

Similarly, with regard to the industrial use of paint strippers, Altnau (2005) presented the following comparison between the costs of a DCM-based dip tank system as opposed to one based on a water-based DBE formulation. It is evident that the cost of the alternative formulation is more than three times more expensive than then DCM-based paint stripper; however, the wastewater treatment required for DCM-based systems is assumed to be so much higher that the overall cost for DCM-based systems is more than double the cost of the alternative.

Table 5.15: Comparative Costs of Paint Stripping Tanks for DCM-based Paint Strippers and for DBE-based Alternative Systems		
DCM dipping tank	**Cost element**	**Water-based DBE dipping tank**
Carbon steel tank: €4,000	Investment for a $4m^3$ tank	INOX steel tank with FLUSH DECAP MOVING® system and filtration section: €16,300
DCM: €8,000	Paint stripper	DBE formulation: €25,600
€88,000	Wastewater treatment	Not applicable
Included	Filtration	Penetrated INOX tank with filter: €1,200
€100,000	***Total***	***€43,100***

Source: Altnau, 2005; Vliegenthart, 2007
Notes:
- the tanks contain the same quantity;
- the DCM-formulation is most probably a mixture of DCM+ methanol+ paraffin wax;
- the cost of wastewater treatment for the DCM-based tank was reportedly calculated by the owners of a DCM-stripping station near Paris. In order to remove all DCM out of the rinse/cleaning water, one needs a complicated filtration system (for example, the maximum allowed concentration of DCM in the sewer in the Netherlands is 10 µg/L(=10 parts per billion) in treated wastewater. For the alternative tank system, the waste needs to be filtered to remove the paint residue and other contaminants and then it may be released direct to the sewer without any further treatment;
- the filtration costs for the DCM-tank is included in the wastewater treatment prices as it was given by the owners of the DCM-stripping station. This information was taken from the Artisan Magazine, Vol 21, February 2005;
- the company that installs the alternative tank system argues that its system becomes much more economical over time due to very little evaporation of the water-based DBE stripper. In other words, the longer the process, the more economical it becomes.

5.13.6 The Importance of Potentially Increased Stripping Times

With some of the alternatives, extended times (beyond those for DCM) will be required for them to act. These extended time frames may not necessarily relate to the ultimate effectiveness of the alternative, but rather a different mechanism of action. As a matter of fact, a number of the alternatives work in a different way from DCM and users would need to alter their working patterns to adapt to the new products if there were a restriction on the use of DCM-based paint strippers.

Suggestions of 12-48 hours waiting time for some formulations have been suggested for paint removal while for graffiti removal an increase of application times by 4 or 5 times have been suggested (Bunnik-Advies, 2007b). The alternatives, however, may remove more coating layers after one application of the product than a DCM-based paint stripper.

For some users, the delay associated with the use of alternative paint strippers may be particularly inconvenient, for example, when the paint stripping activity involves the treatment of small areas perhaps located far away from each other, as is the case with certain professional uses (‘spot cleaning’ during graffiti removal (Bunnik-Advies, 2007b)). A UK user who specialises in graffiti removal (from schools, public buildings, underground stations, etc.) has suggested that, if his operations were to be prolonged due to the use of a slower-acting chemical formulation, he would have to spend more time on any one job before travelling, potentially several kilometres away, to undertake another cleaning operation. Evidently, if a number of small-scale jobs were located in close proximity he could feasibly apply the paint stripper on one substrate and then let the stripper act while he applies the stripper on another substrate nearby and so forth. However, in most cases his jobs are located apart from each other and a slower acting product would disrupt his business significantly. In the case of an underground station, it is important that any paint stripping/cleaning operations are quick because the Underground network may only stay closed for a few hours overnight. It is has to be noted that alternative paint stripping methods are already in use in these applications. For instance, one professional user indicates that most graffiti on the underground is on hard or painted surfaces and is normally removed by specialised graffiti removing chemicals that require mechanical assistance (rather than DCM-based paint stripping).

Use of some of the alternatives may thus require a number of successive visits across a number of customer locations – which may be logistically impossible. The user may thus have to turn down work and most likely charge the customer an additional fee for the increased labour costs or his 'idle time'.

Moreover, if the paint stripper needs to be left overnight on the substrate, then, in some cases, it may be necessary to take measures to prevent the access of the public into the stripping area or even ensure that adequate supervision will be in place. A fast acting DCM-based paint stripper speeds up the work programme and minimises inconvenience on works site. In some cases, this means that the product spends less time on the substrate and the potential for substrate damage is potentially reduced.

On the other hand, other time-consuming activities that are associated with the use of DCM-based paint strippers (e.g. wearing of PPE and introducing and removing any forced ventilation systems etc.) are most likely to be avoided when alternatives are used (although some types of alternatives may require similar engineering controls and the use of PPE). There is also the potentially lower exposure to potentially hazardous chemicals when using alternatives as the user needs to wait longer times away from the treated surface. Cleaning up the residue on the substrate after the removal of paint using a DCM-based paint stripper has also been suggested as being messy and time-consuming.

In general, it is considered that time considerations are of most relevance to professional and industrial uses. While consumers would naturally prefer a fast-acting product, they usually carry out stripping in their leisure time and, generally, can afford to wait longer times for the stripper to act.

5.13.7 Flammability of Alternative Formulations

An issue raised in the course of this study is that replacement of DCM-based paint strippers with alternatives may result in more widespread use of flammable products which may in turn result in a higher incidence of fires with the associated loss of property, life or injury. This is also referred to in the German Technical Rule TRGS 612 according to which "*in comparison with methylene chloride-based paint strippers, the* *solvent-based methylene chloride-free paint strippers pose an increased fire and explosion risk if the methylene chloride-free strippers are labelled with phrases R 10 or R 11, or if they are sprayed. In such cases, the formation or presence of explosive vapour/air mixtures must be expected throughout the duration of work. During spraying, explosive mist/air mixtures must be expected. In all these cases, appropriate protective measures in accordance with § 12 of the German Hazardous Substance Regulations must be taken (see Appendix 1)*" (BMAS, 2006).

Supporters of DCM-based paint strippers (in the UK) have indicated that a significant number of fires in the UK involve flammable liquids and an even more significant number of deaths are associated with fires where the material of first ignition was a flammable liquid making the presence of flammable liquids a key risk indicator. The most recent publicly available fire statistics for the UK (for the year 2004) shows that out of a total of 37,582 fires in "other buildings" (not dwellings) with 55 fatalities and a total of 1,519 non-fatal injuries, liquid flammable materials accounted for 1,763 incidents with 7 deaths and 178 non-fatal injuries. Among them, the vast majority are associated with petroleum, diesel oil/fuel oil, other oils, spirits and "other". The only categories under which paint strippers may fall are paints and varnishes, and other. These two categories account for a total of 474 incidents, 2 deaths and 40 non-fatal injuries (no death is associated with paints and varnishes). These last figures represent only 1.3% of all incidents, 3.6% of fatalities (associated with "other" materials) and 2.6% of non-fatal injuries (OPDM, 2006).

In dwellings, a total of 59,743 fire incidents were reported in 2004 with 375 fatalities and 11,977 non-fatal injuries. Liquid flammable materials (as the material or item first ignited) account for 1,310 incidents with 25 deaths and 369 non-fatal injuries. Paints and varnishes account for 139 incidents with 9 non-fatal injuries only while "other" account for 295 incidents with 6 deaths and 117 non-fatal injuries. The totals of 139+295 = 434 incidents, 6 deaths and 9+117 = 126 non-fatal injuries represent 0.7% of incidents, 1.6% of deaths and 1% of non-fatal injuries of the grand totals for dwelling fires (OPDM, 2006).

Overall, the percentage of incidents, deaths and injuries from fires starting from the flammable liquid groups paint strippers might fall under are very low. If we assume that paint strippers would fall under the paints and varnishes group, the percentages would be only a faction of a percentage.

Moreover, while it is the case that some alternatives are flammable, there is also evidence that DCM-based paint strippers could be flammable as well. Communication with a DCM manufacturer suggests that "*for classical paint strippers with methylene chloride/methanol blends, methylene chloride being more volatile than methanol, the methanol content increases more and more in the paint stripper. As methanol is flammable, there is a composition for which the blend becomes flammable (the methylene*

chloride content is too small to extinguish the flammability of methanol)"[45]. Safety Data Sheets for DCM-based paint strippers occasionally the product as "Flammable".
It should be noted that the presence of flammable liquids affects the practices of both manufacturers and users. A German manufacturer of paint strippers suggests that, when using flammable materials in Germany, you are required by law to ensure an air exchange rate of 5 times/hour by law. A UK manufacturer of paint strippers indicates that "*we are only allowed to handle and store a certain level of flammable liquids in our warehouse. If we have to change from DCM containing paint strippers to formulations that contain high levels of flammable solvent, the volumes that we would be required to store may take us over the limit that we are allowed to keep. This would mean we may have to build or rent additional storage space for this product, leading to increased costs for the company*".

5.13.8 Potential for Solvent Abuse Linked to the Use of Alternative Formulations

The issue of volatile substance abuse has been examined following the comments from a number of consultees on the suitability of alternatives. More specifically, some manufacturers of DCM and DCM-based paint strippers have suggested that a restriction on the marketing and use of DCM-based paint strippers could result in increased sales of alternative paint stripping formulations that contain substances such as methanol, xylene, toluene, ethyl acetate, methyl ethyl ketone (MEK) and dimethyl ether, substances which, in theory, could be abused.

In order to address these concerns, a literature search was undertaken to establish the extent of the problem of volatile substance abuse, the role of paint strippers in it and the likelihood of the alternative formulations resulting in an increase in volatile substance abuse. The full findings of our analysis are presented in Annex F to this report.

We have requested the assistance of experts in Member States from the European School Survey Project on Alcohol and Other Drugs (ESPAD) which has collected in the recent past information on volatile substance abuse in individual Member States. Unfortunately, only a small number of experts from a total of five Member States responded to our consultation.

Some information was received specifically from the UK, one of the countries with a documented volatile substance abuse problem according (see Annex F). According to experts from St George's Hospital, University of London (Ramsay, 2007), the hospital collects the UK mortality data for the UK Department of Health and has done so in a uniform manner since about 1984. Over that time the number of deaths reached a peak of 152 in 1990 and have since declined to an all-time low of 47 in 2004 - the most recent year for which published data are available. The relevant reports are available on the following Internet site: www.vsareport.org.

45 The manufacturer notes that below 78% of methylene chloride, the blend becomes flammable (this assertion is based on Kirk-Othmer (1996): Encyclopaedia of Chemical Technology, Fourth edition, Vol 17, 1996, p. 1072).

It appears that, in the UK, between1984 and2004, the focus has changed from toluene containing adhesives to butane from cigarette lighter refills. Paint stripper has never featured highly on the list of abused products (16 deaths have been recorded for both paint thinners and strippers out of a total of 2,258).

A key UK expert with a long involvement in the monitoring of volatile substance abuse was of the opinion that "*reformulation to remove dichloromethane in my view would not materially change the situation*" (i.e. paint strippers and thinners being responsible for only 0.7% of all UK deaths since records began).

On the basis of our literature review and discussions with experts), the following conclusions may be reached:

- volatile substance abuse is a serious social issue which may be quite complex to interpret and address. The degree of this problem varies among Member States;
- DCM itself may be abused by inhalation; in fact, paint strippers (alongside paint thinners) already feature in existing statistics and on lists of abusable products. DCM is specifically mentioned as an abusable component of relevant products;
- there is a considerable number other products and substances (e.g. gas fuels, aerosols and adhesives) which feature much more regularly than paint strippers and DCM in the agents linked to abuse and associated deaths;
- the possible contribution of paint strippers in deaths from substance abuse is very limited in the UK. While it cannot be certain that the situation in the UK is representative of the rest of the EU, it should be noted that the DIY use of paint strippers (especially DCM-based ones) in the UK is widespread and much larger than in most of other domestic European DIY markets i.e. it can be assumed that access to DCM-based paint strippers could be more frequent in the UK households;
- paint strippers are generally relatively expensive abusable products: lighter fuel is much cheaper and more easily accessible to potential abusers than paint strippers. Additionally, it is possible that paint strippers that may replace DCM-based ones may be even more costly than DCM-based formulations, thus making them less attractive to potential abusers;
- someone who intends to abuse volatile substances would prefer to do so without the presence of additional components some of which might be toxic rather than adding to the 'pleasant' sensation of inhalation. Paint strippers contain several components such as thickeners, vapour retardants etc. which make their abuse more complicated and less 'satisfactory'; and
- some substances, the abuse of which may in theory increase after a theoretical restriction on DCM-based paint strippers, are already components of DCM-based paint strippers (methanol, toluene) currently on the market. Naturally, the

concentration of these substances in alternative formulations would have to play an important role to the attractiveness of these products.

In conclusion, it is considered that a potential restriction on the marketing and use of DCM-based paint strippers is unlikely to cause a significant increase in volatile substance abuse in the EU.

5.14 Summary and Conclusions

5.14.1 Technical Suitability of Alternatives

On the basis of the available evidence and the views of different consultees that we have collected thus far, the following may be concluded with regard to the technical suitability of alternatives:

- technically suitable alternatives to DCM-based paint strippers are generally available on the market;

- it is neither possible nor feasible to select a specific substance or technique as being the most appropriate for paint stripping. This is because each of the paint stripping formulations and techniques considered has unique advantages and disadvantages, which vary by formulation strength, paint stripping application and/or substrate. Consultation also supports the idea that alternatives might not be as universally effective as DCM-based paint strippers. Even by consultees who are in favour of restrictions on the marketing and use of DCM-based paint strippers (for instance, the Danish Paintmakers' Association). This should not be interpreted as evidence that DCM-based paint strippers are the best performers in all occasions. Available testing results (see for instance the results of the testing undertaken on behalf of the EASCR – Section 5.13.2);

- the performance of a paint stripper also depends on the experience and competence of the formulator and stripper (as much as on the substance/technique used) and on whether the user is able or, in principle, willing to follow the instructions of each paint-stripping method;

- as would be expected, for some applications, the introduction of an alternative substances or techniques (as a result of any restrictions) may be simple and 'seamless', while for other applications, it may be more complicated. Time delay issues have particularly been highlighted by some consultees, especially when 'small' quick jobs need to be undertaken. Time considerations are more relevant to professional uses and industrial uses rather than DIY applications. At the same time, it can be argued that users are currently saving time and avoid inconvenience by not employing the appropriate measures for the protection of their safety or health;

- in the event of a restriction on DCM-based paint strippers, users would need to undertake a more detailed assessment of the task at hand and of what the necessary stripping materials should be (unlike the situation with DCM, which allows for several types of coatings to be removed often without the user knowing what type of coating he is dealing with). This would require more focus and knowledge from the user[46] and, it can be argued, that this would raise the standards in the industry; and

- finally, and most importantly, it is important to look at countries that have already restricted the use of DCM-based paint strippers. These provide a real-life example of the situation after the introduction of a restriction. We do not have any concrete evidence that users in the key three countries (Austria, Denmark and Sweden) have faced insurmountable problem when switching from DCM-based products to alternatives. In fact, in the last two countries where users may apply for permission to use DCM-based products, no such applications have been received for the uses under consideration in this report. On the other hand, we note the concerns of the Austrian industry (FCIO) with regard to the lack of harmonisation that may have adversely affected Austrian enterprises. The recommendations for actions in this report should take into consideration the need for harmonising the internal market.

5.14.2 Risks to Human Health and the Environment from Alternatives

In terms of risks to human health and the environment, each paint stripping method may have effects on human health and the environment, as a matter of fact, not all alternative paint strippers may be considered to be safer than DCM-based paint strippers (see issues surrounding the use of NMP following its recent reclassification as Repr. Cat. 2). In practice, inappropriate use of any of the alternative paint stripping methods can result in serious effects. For instance, if mechanical methods are not used appropriately, chemical methods may be preferable, given the greater knowledge of the effects that their known components have on health and the environment (MST, 2002). Neither should it be assumed that the use of alternatives would not be accompanied by the need for a proper assessment of the risks and the use of appropriate engineering controls and PPE for workers.

Also, the discussion in this Section has focused on a selection of 'active' substances without addressing the potential hazards to human health and the environment from all components of alternative formulations (or the remaining components of DCM-based paint strippers for that matter).

However, it is evident that DCM has a unique profile of adverse effects to human health coupled with being a priority substance under the Water Framework Directive. Also, because of its high concentration in paint stripping products, its high volatility and narcotic effects, DCM poses a direct risk of death as a result of misuse[47] (a characteristic

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46 Choosing the appropriate stripping method requires a consideration of many factors such as the location, size and composition of the object to be stripped, the substrate, and the nature of the coating (as well as operating costs, environmental impact and worker safety). For instance, the size and location of the object may restrict the type of technique that can be used and the composition of the object to be stripped may limit the kinds of the stripping techniques that can be used.

47 Importantly, although DCM-based paint strippers should used after careful consideration of the risks by the employers (or consumers) and with the appropriate engineering controls and PPE, this is very often not the

not necessarily shared by most of the alternatives). On balance, there are alternatives with a much better human health and environmental hazard and risk profile.

5.14.3 Cost of Alternatives

Cost is clearly a consideration in the choice of paint stripping product, however, perhaps not the most important as shown in a recent survey in the UK and Ireland (see Section B27.4 in Annex B to this report where the cost of formulation is suggested to be the least important factor).

Several consultees have emphasised the increased per unit cost of most alternatives (except perhaps caustic products). However, the cost per kilogram of a product is far from an adequate indicator of its overall cost. The 'real' cost of a paint stripping formulation/method involves the cost of the equipment, the time required for a job to finish, the quantity of paint stripper required per square metre of stripped surface, the cost of purchasing, using and replacing promptly the necessary ventilation equipment and PPE and the cost of disposing of any generated waste during the stripping operation.

While users of DCM-based paint strippers frequently highlight that they are quick, effective and inexpensive products, this often mainly relates only to the per kg cost of the product. It is important to consider that the types of PPE and engineering controls currently employed by users is often inadequate. Assuming that proper engineering controls and PPE were used, the cost comparison would be different. Table 5.14 presents an example comparison of costs of PPE when DCM-based products and alternative products are used. The cost difference is very significant. Therefore, an increased per kilogram cost of an alternative may in fact be accompanied by a reduction in the actual overall cost of stripping due to the need for less costly PPE and waste disposal. Of course, not all alternative formulations or methods may require less costly PPE or waste disposal.

It is also important to note that the paint stripping sector, as a whole, is characterised by stable demand as it is an essential process (i.e. an activity which has to be undertaken as required) for the metal treatment, construction, home decoration (DIY) and building restoration and maintenance markets. Any restrictions (or price increases) imposed on a particular paint-stripping product are thus unlikely to have a significant impact on demand – rather an increase or redistribution of costs amongst relevant manufacturers, formulators and users. In this regard, it should be borne in mind that several manufacturers of DCM-based paint strippers in the EU also manufacture DCM-free alternatives. Importantly, some of those companies that have an established presence in the DCM formulations market also have a key role in the alternatives market.

The issue of costs from a potential restriction on the marketing and use of DCM-based paint strippers is discussed in more detail in Section 8.

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case. Moreover, the equipment necessary is both costly and uncomfortable and, as such, users are reluctant to use it.

6. POSSIBLE FURTHER RISK REDUCTION MEASURES

6.1 Rationale for Introduction of Further Risk Reduction Measures

Following from the analysis in the previous Sections, it is considered that further risk reduction measures are required on the basis of:

- *the past work on the evaluation of risks (see Section 3)*: the results of two risk assessment reports (TNO, 1999 and ETVAREAD, 2004) show that risk reduction measures are required for some applications of DCM-based paint strippers;

- *excessive exposure levels (see Annex D)*: the available information (where this includes actual and simulated measurements) on exposure levels during consumer (DIY), professional and industrial use of DCM-based paint strippers, which shows that exposure levels invariably exceed the nationally set OELs;

- *lack of sufficient user protection (based on an analysis of existing risk reduction measures (see Section 4))*: the available information on current safety practices (legislative and non-legislative) among paint strippers, especially with regard to the use of personal protective equipment, shows that users of DCM-based formulations may not have sufficient levels of protection (through a combination of bad practice, product misuse, inadequate advice from manufacturers and inadequate enforcement by the national authorities); and

- *accidents and fatalities (see Annex E)*: the several accidents and fatalities which have occurred in Europe and elsewhere as a result of the use (or misuse) of DCM-based paint strippers.

Any recommended risk reduction strategy, therefore, has two principal objectives:

- to reduce the exposure and risks to human health associated with the continuing

- to ensure that no further fatalities occur and that any continuing users of DCM are well informed and/or protected against the associated risks.

This Section discusses the types of risk reduction measures which are available for achieving these objectives.

6.2 The Range of Possible Risk Reduction Measures

Types of risk reduction measures (i.e. practical measures for risk control) that could be applied to the use of DCM-based paint strippers are outlined in the relevant Technical Guidance Document (TGD) (EC, 1998). The measures relating to manufacture, industrial and professional use of substances are outlined in Box 6.1, while Box 6.2 outlines the measures relating to domestic and consumer use.

Box 6.1: Possible Risk Reduction Measures for Manufacture and Industrial/Professional Use
• Controls on manufacture; • restrictions on the marketing and/or use of the substance under Directive 76/769/EEC; • re-designing the process itself, or changing the substances or materials used in it; • safe systems of work, such as specified standards of physical containment or extraction ventilation; • application of good manufacturing practice, for example, under ISO standards; • classification and labelling; • separation of personnel; • monitoring and maintenance of equipment; • dust suppression methods, such as the use of substances in tablet or pellet form; • occupational exposure limits and/or air monitoring in the workplace; • accurate hazard information (for example, safety data sheets), and/or better delivery of safety information, such as clearer labelling or the provision of warning signs in the workplace; • biological exposure indices and/or biological monitoring of workers; • medical surveys of workers; • training; • use of personal protective equipment; • licensing of operators of certain operations; • 'end-of-pipe' controls to minimise, neutralise or render less harmful any emissions than cannot practicably be avoided otherwise; • limit values for emission and effluent monitoring; and • environmental quality standards and/or environmental monitoring.
Source: EC, 1998

Box 6.2: Possible Risk Reduction Measures for Domestic and Consumer Use
• Restrictions on the size of container; • design of containers including non-spill or narrow-neck containers; • limits on concentrations of components; • product design changes, e.g. encapsulation; • limits of the overall quantity available to each user; • addition of an emetic, a stanching agent or a colorant; • restrictions on use; • classification and labelling; • hazard warnings and/or use instructions on packaging; • tactile danger warnings; and • child resistant closures.
Source: EC, 1998

6.3 Identification of Possible Risk Reduction Measures

6.3.1 Initial Screening of Possible Risk Reduction Measures

In order to identify measures that are suitable for further consideration in this strategy, the measures identified in Box 6.1 and 6.2 have been screened in order to eliminate those that are not relevant to DCM-based paint strippers.

The following have thus been removed from the list of measures relating to the professional and industrial use of DCM-based paint strippers (Box 6.1):

- *controls on manufacture* (this is not relevant to the identified risks from DCM-based paint strippers);

- *application of good manufacturing practice, for example, under ISO standards* (this is not relevant to the identified risks from DCM-based paint strippers);

- *classification and labelling* (there is no new information that requires new/additional classification or labelling of DCM under Directive 67/548/EEC or the classification and labelling of DCM-based paint strippers under Directive 1999/45/EC; other types of (voluntary) labelling may be considered under the "*accurate hazard information*" measure);

- *separation of personnel* (this is not relevant to the identified risks);

- *monitoring and maintenance of equipment* (the identified risks do not relate to lack of equipment maintenance);

- *dust suppression methods, such as the use of substances in tablet or pellet form* (the products concerned are not in powder form);

- *biological exposure indices and/or biological monitoring of workers* (while this may provide further information for risk assessment, it is not relevant for addressing the immediate risks from DCM-based paint strippers);

- *medical surveys of workers* (while this may provide further information for risk assessment, it will not address the immediate risks from DCM-based paint strippers);

- *'end-of-pipe' controls to minimise, neutralise or render less harmful any emissions than cannot practicably be avoided otherwise* (this relates to risks to the environment which are not the primary focus of this study);

- *limit values for emission and effluent monitoring* (this relates to risks to the environment which are not the primary focus of this study); and

- *environmental quality standards and/or environmental monitoring* (this relates to risks to the environment which are not the primary focus of this study).

The following can be removed from the list of measures relating to the domestic and consumer use of DCM-based paint strippers (Box 6.2):

- *limits on concentrations of components* (this measure may not be feasible as DCM-based paint strippers require a certain and significant percentage of DCM to be effective. Furthermore, it is currently unclear whether risks would be adequately controlled if the concentration of DCM was below a certain threshold);

- *design of containers including non-spill or narrow-neck containers* (this should already be the norm based on current legislative requirements (see Section 4.1.1);

- *product design changes, e.g. encapsulation* (this is of no relevance to the types of products which give rise to risks;

- *limits of the overall quantity available to each user* (this appears to be unworkable as it would require that retailers communicate information whenever a single consumer purchases a product so that further purchases (if a set limit is exceeded) may not be authorised);

- *addition of an emetic, a stanching agent or a colorant* (the identified risks do not relate to intentional or unintentional consumption/digestion of DCM-based paint strippers, although some accidents involving ingestion have been documented);

- *classification and labelling* (there is no new information that requires new/additional classification or labelling of DCM or DCM-based paint strippers under Directives 67/548/EEC or 1999/45/EC; other types of labelling may be considered under the "*hazard warnings and/or use instructions on packaging*" measure);

- *tactile danger warnings* (the identified risks are not specifically related to the use of DCM-based paint strippers by blind or partially sighted consumers); and

- *child resistant closures* (this should already be the norm based on current legislative requirements (see Section 4.1.1).

Therefore, the following potential measures will be considered:

<u>Manufacture and Industrial/Professional Use</u>

1. Restrictions on the marketing and/or use of the substance under Directive 76/769/EEC;
2. re-designing the process itself, or changing the substances or materials used in it;
3. safe systems of work, such as specified standards of physical containment or extraction ventilation;
4. occupational exposure limits[48] and/or air monitoring in the workplace.

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48 The Commission has indicated that the issue of occupational exposure limits for DCM is currently being discussed by the Scientific Committee on Occupational Exposure Limits (SCOEL).

5. accurate hazard information (for example, safety data sheets), and/or better delivery of safety information, such as clearer labelling or the provision of warning signs in the workplace;
6. training;
7. use of personal protective equipment; and/or
8. licensing of operators of certain operations.

Domestic and Consumer Use

1. Restrictions on the size of container;
2. restrictions on the placing on the market (under Directive 76/769/EEC); and/or
3. hazard warnings and/or use instructions on packaging.

6.3.2 Possible Means of Implementing the Identified Risk Reduction Measures

For the three broad categories of use of DCM-based paint strippers, the potential measures listed above may be implemented in practice in the forms presented in Tables 6.3 and 6.4. The TGD (EC, 1998) identifies a range of possible administrative, legal and/or other tools that could be used to take forward proposed risk reduction measures. These are as follows:

- *information programmes and other EC/government initiatives*. This could take the form of the dissemination of accurate hazard information to workers (i.e. those involved in industrial and professional applications) and consumers on DCM and DCM-based paint strippers by industry or government departments and agencies;

- *technical standards and authoritative guidance* (statutory, advisory or voluntary);

- *unilateral action by industry* (the TGD indicates that additional risk reduction measures may be necessary unless unilateral action is taken by the majority of firms involved);

- *voluntary agreements* (such as negotiated agreements between industry and governments). These could also be used to alter the processes or products involved in order to reduce the risks, to better control emissions of, or to cease the use of DCM-based paint strippers;

- *economic instruments* including taxes (such as emission taxes or product taxes), subsidies or tradeable permits. These could be used to either reduce emissions to the environment or to reduce the use of DCM-based paint strippers; and

- *regulatory controls*, including more effective enforcement of existing controls, amendments to existing legislation or new legislation (such as uniform EU controls, target based controls (e.g. on the amount released to air) or restrictions on marketing and use).

Of these six tools, only three (*information programmes and other EC/government initiatives*, *technical standards and authoritative guidance* and *regulatory controls*) are potentially relevant for addressing the risks from DCM-based paint strippers.

With regard to *unilateral action*, no respondents to our consultation exercise have particularly indicated that they would be willing to assume unilateral action with regard to DCM-based paint strippers. Also, given that on an EU-wide basis, there are a large number of installations using DCM-based paint strippers with the majority being SMEs, it is concluded that this potential measure cannot be considered further. For the same reasons, a *voluntary agreement* is not considered relevant since its uptake by the industry sectors involved and its effectiveness cannot be guaranteed. With regard to *economic instruments* and the scope for their use, it is considered that they:

- cannot guarantee the desired reduction of exposure to DCM to acceptable levels;
- are not easy to set up or manage especially where a large number of SMEs are involved (as is the case with DCM-based paint strippers); and
- would require significant resource inputs to establish comprehensive monitoring..

6.3.3 Consolidation of Types of Measures

Overall, Tables 6.3 and 6.4 include:

- eleven possible risk reduction measures for industrial and professional uses; and
- eight possible risk reduction measures for consumer uses.

The 'do nothing' option has also been considered for all three use categories. For these remaining potential risk reduction measures, there are certain similarities in terms of the changes that they imply and their prospective means of implementation. They have thus been divided into two categories of measures namely:

- **restrictive measures**: the relevant measures under this category, involves placing restrictions on the marketing and use of DCM-based paint strippers. In theory, these could be applied to all or some of the uses of these products, implying cessation of use(s) or a phase out over a certain period in time; and
- **non-restrictive measures**: the relevant measures under this category (i.e. setting occupational exposure limits for DCM, providing additional information, advice and training to users) reflect changes to reduce exposure to DCM rather than changes that eliminate the use of DCM. These measures would typically be implemented *via information programmes and other EC/government initiatives*, *technical standards and authoritative guidance* and potentially allow individual industries and Member State Competent Authorities to choose the means of implementation. They can also be implemented by means of a range of existing Community-level legislation (transposed by legislation in the Member States).

Table 6.3: Possible Risk Reduction Measures for Industrial and Professional Uses of DCM-based Paint Strippers

Generic type of measure	Possible forms for industrial uses	Possible forms for professional uses
Baseline	Do Nothing	Do Nothing
Restrictive measures		
Restrictions on the marketing and/or use of the substance under Directive 76/769/EEC	A8. Total prohibition (ban) on all industrial uses of DCM-based paint strippers.	B8. Total prohibition (ban) on all professional uses of DCM-based paint strippers.
Safe systems of work, such as specified standards of physical containment or extraction ventilation (See A3)	A9. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless used in strictly controlled conditions A10. Prohibition (ban) on all industrial uses of DCM-based paint strippers in enclosed spaces (*this is based on the analysis of information on fatal accidents*).	B9. Prohibition (ban) on all professional uses of DCM-based paint strippers unless used in strictly controlled conditions B10. Prohibition (ban) on professional use of DCM-based paint strippers in enclosed spaces.
Use of personal protective equipment	A11. Prohibition (ban) of all industrial uses of DCM-based paint strippers unless appropriate personal protective equipment is used.	B11. Prohibition (ban) of all professional uses of DCM-based paint strippers unless appropriate personal protective equipment is used.
Re-designing the process itself, or changing the substances or materials used in it	A12. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two possible thresholds*). A13. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (*possible thresholds: 5,000 ml or 1,000 ml*).	B12. Prohibition (ban) on all professional uses of DCM-based paint strippers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two possible thresholds*). B13. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (possible thresholds: 5,000 ml, 1,000 ml or 500 ml).by a qualified licensed tradesman.
Licensing of operators of certain operations	A14. Prohibition (ban) on the use of DCM-based paint strippers unless used by a qualified licensed (industrial) user.	B14. Prohibition (ban) on the use of DCM-based paint strippers unless used by a qualified licensed (professional) user
Non-restrictive measures		
Occupational exposure limits and/or air	A12. Establishment of a Community-wide occupational exposure	B12. Establishment of a Community-wide occupational exposure

Table 6.3: Possible Risk Reduction Measures for Industrial and Professional Uses of DCM-based Paint Strippers

Generic type of measure	**Possible forms for industrial uses**	**Possible forms for professional uses**
monitoring in the workplace	limit for DCM.	limit for DCM.
Accurate hazard information (for example, safety data sheets), and/or better delivery of safety information, such as clearer labelling or the provision of warning signs	A13. Provision of additional information (in addition to what is provided for by the Classification and Labelling legislation in Safety Data Sheets) on using DCM-based paint strippers under conditions of adequate ventilation. A14. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.	B13. Provision of additional information (in addition to what is provided for by the Classification and Labelling legislation in Safety Data Sheets) on using DCM-based paint strippers under conditions of adequate ventilation. B14. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.
Training	A15. Provision of training to users involved in industrial uses to ensure that DCM-based paint strippers are used with appropriate personal protective equipment and conditions of ventilation as well as provision of instructions on appropriate emergency action.	B15. Provision of training to users involved in professional uses to ensure that DCM-based paint strippers are used with appropriate personal protective equipment and conditions of ventilation as well as provision of instructions on appropriate emergency action.
*Measures A9, A10 & A11 (*as well as *B9, B10 & B11)* are broadly interlinked and would work most effectively when complementing one other and/or if implemented together. For instance, provision of training (or advice) will invariably involve provision of information. On this basis, these measures will be assessed as a single measure: *provision of additional information, advice and training on using DCM-based paint strippers under conditions of adequate ventilation, the use of appropriate personal protective equipment and provision of instructions on appropriate emergency action.*		

Table 6.4: Possible Risk Reduction Measures for Consumer Uses of DCM-based Paint Strippers	
Generic type of measure	**Possible forms for consumer uses**
Restrictive measures	
Restrictions on use (under Directive 76/769/EEC)	C1. Total prohibition (ban) on all consumer uses of DCM-based paint strippers. C2. Prohibition (ban) of self-service sale of DCM-based paint strippers. C3. Prohibition (ban) on consumer use of DCM-based paint strippers in enclosed spaces (for example, basements, small rooms without windows, etc.). C4. Prohibition (ban) of sales of DCM-based paint strippers unless sold along with appropriate personal protective equipment. C5. Prohibition on sales of DCM-based paint strippers to consumers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*two threshold values*).
Restrictions on the size of container	C6. Prohibition (ban) of sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (*possible thresholds: 500 ml or 1,000 ml*).
Non-restrictive measures	
Hazard warnings and/or use instructions on packaging	C7. Provision of additional information (on containers or accompanying technical literature) on using DCM-based paint strippers under conditions of adequate ventilation (i.e. clear warnings on containers restricting the use of DCM-based paint strippers in closed spaces or without adequate ventilation). C8. Provision of advice on the use of appropriate personal respiratory protection equipment and of gloves made of suitable chemical-resistant material.
Measures C7 & C8 are broadly interlinked and would work most effectively when complementing one other and/or if implemented together. On this basis, these two measures will be assessed as a single measure: *Provision of additional information and advice on using DCM-based paint strippers under conditions of adequate ventilation and appropriate PPE.*	

7. ASSESSMENT OF POSSIBLE RISK REDUCTION MEASURES

7.1 Introduction

The TGD specifies that possible further risk reduction measures should be examined against the following four decision criteria: effectiveness, practicality, economic impact and monitorability.

The following discussion, therefore, provides an assessment of the potential risk reduction measures for DCM. Each of the possible measures identified in Section 6 is considered in turn, with information presented on the performance of the measures against the four key criteria listed above.

7.2 The 'Do Nothing' Option

Section 4.10 has discussed the effectiveness of the existing risk reduction measures (effectively the 'do nothing' option). The discussion therein concluded that further risk reduction measures are necessary to protect the health and safety of the users of DCM-based paint strippers and to prevent accidents that result in fatalities and injuries among the users of these formulations. Therefore, the 'do nothing' option for all three use categories (industrial, professional and consumer use) would not effectively protect the users, is not acceptable and will not be considered further in our analysis.

7.3 Effectiveness of Possible Risk Reduction Measures

7.3.1 Introduction

There are two sub-criteria against which the effectiveness of a risk reduction measure may be assessed:

- the *risk reduction capacity* of the risk reduction measure: the most important characteristic of any risk reduction measure should be the ability of the measure to reduce the risk to acceptable levels. Generally, a measure that cannot ensure a sufficient level of risk reduction will either have to be complemented by another measure or will be eliminated from further consideration; and

- the *proportionality* of the risk reduction measure: the proposed measure should be one that:
  - targets the identified risk;
  - corresponds in amount or degree to the effects of the adverse effects suffered or the adverse effects that are being avoided taking into account the available scientific evidence;
  - requires that risk management action is taken by those responsible for the risks (and that these actors have the authority and information to act accordingly);

- takes into consideration the length of time allowed for the actors to comply with the measure including the time required for the adoption of alternatives, where applicable;
- is consistent with legal requirements already in place; and
- ensures a good balance between costs and effectiveness.

7.3.2 Effectiveness of Restrictive Measures

Analysis of a Total Ban on Marketing and Use of DCM-based Paint Strippers

A total ban on the marketing and use of DCM-based paint strippers would ensure that the human health risks arising from these products are eliminated. By its nature, this measure provides maximum effectiveness and certainty in dealing with risks from DCM-based paint strippers and can be implemented relatively quickly.

Such a measure would require:

- manufacturers of DCM-based paint strippers to replace DCM in their formulations with an alternative chemical or replace the DCM-based formulations with new DCM-free formulations. Several of these companies already manufacture and supply alternative formulations, therefore, they may simply shift their focus from their DCM-based products to the alternatives they place on the market;

- users to use alternative paint stripping formulations or techniques in order to perform their paint stripping operations.

<u>Issues of Risk Reduction</u>

The advantages of a total ban on all uses of DCM-based paint strippers would include:

- the elimination of the human health risks from these formulations;
- the prevention of (mainly) work-related accidents result in users being injured or losing their lives;
- the harmonisation of the internal market and the level playing field that will be established; and
- indirectly, the reduction of risks from DCM to the environment; this would occur because a total ban would support the objectives of the Water Framework Directive with regard to emissions of DCM which is a priority substance under the said Directive.

Possible disadvantages might include:

- the potential risks to human health (and possibly to the environment) from the use of alternative paint stripping methods.

The discussion in Section 5 shows that there exist alternative solvents which have a hazard/risk profile more favourable than DCM (less volatile, no classification as carcinogens, etc.), however, this does not apply to all alternatives. As shown already, NMP, for instance, is a Repr. Cat. 2. It is important to consider that alternatives will generally have their own issues of safety and health and will need to be used in a responsible way following a potential ban on DCM.

A reduction in risks following a ban will no apply uniformly across the EU. In a small number of Member States, national restrictions apply. In these countries there will be limited benefit from a ban on DCM-based paint strippers; however, their industries would potentially benefit from the harmonisation of the market which would mean that competitors in other EU Member States would be subject to the same restrictions. Similarly, for Member States where the use of DCM-based paint strippers is limited at present, the benefits from a ban would be limited. Finally, a ban would also confer no discernible benefit to companies which comply fully with the law at present and take all necessary measures to protect the health and safety of their employees and their customers.

<u>Issues of Proportionality</u>

A total ban on DCM-based paint strippers may raise issues of proportionality. The pivotal factors in assessing the proportionality of such a sweeping measure would be:

- the correspondence to the degree of risk;
- the balance between costs and benefits; and
- the consistency with existing legal requirements.

With regard to the degree of risks, our analysis shows that accidents, whether fatal or not, are invariably the result of inappropriate use of the paint stripper (e.g. inadequate ventilation, use of wrong type of PPE, etc.). On the other hand, the properties of DCM (e.g. its ability to suppress the CNS), the quantities of the formulations used and the concentration of DCM in them require action to be considered for the better control of risks.

Regarding costs and benefits, a ban would impact upon a range of stakeholders, apart from the manufacturers of DCM-based formulations, the downstream users of these products and potentially the consumers too. On the other hand, it has been established that users avoid at present a significant cost, that of purchasing and using the appropriate PPE. If the appropriate equipment was indeed used, the cost of a ban would not appear to be as high as is claimed by some stakeholders.

Finally with regard to consistency with existing legal requirements, a risk reduction measure will ideally deliver the required reduction in risks by building and supplementing what is already there and where possible using frameworks and possibilities that are available at present. In other words, where the required reduction in risks can be achieved through existing legislation or by limited modification of existing legislation, such a measure would be considered more favourably than an outright ban which may create significant disruption.

In light of potential issues of proportionality, apart from the total bans for each of the use categories (*Measures A1, B1 & C1*), we will consider the merits of more targeted restrictions such as restrictions targeting the use of DCM-based paint strippers:

- unless used in strictly controlled conditions (*Measures A2 & B2*) (see Box 7.1for an explanation on the meaning of the term "strictly controlled conditions" in this study);

Box 7.1: Key Features of "Strictly Controlled Conditions" of Use in the Context of Potential Restrictions
"Strictly controlled conditions" means conditions under which exposure of the user to DCM is limited at levels below the existing national OELs at all times and where possible eliminated. In the context of paint stripping, strictly controlled conditions would require that: a) fluororubber gloves are used during all paint stripping activities; b) effective local exhaust ventilation and mechanical ventilation (e.g. fans) are installed to provide make up air (where this takes into account, existing occupational exposure limits under Directive 98/24/EC) OR an independent air supply respirator (breathing apparatus with separate air supply) is worn at all times; and c) the sides and top of all dip tanks are enclosed and a separate ventilated area provided for drying finished articles.

- in enclosed spaces (*Measures A3, B3 & C3*);

- unless independent air supply respirator (breathing apparatus with separate air supply) and suitable skin protection equipment (gloves) are used (*Measures A4, B4 & C4*);

- unless vapour retardants are used to the effect that the percentage weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (*Measures A5, B5 & C5*);

- unless products are supplied in containers of volume smaller than a certain threshold (*possible thresholds: 500 ml, 5,000 ml or 1,000 ml*) (*Measures A6, B6 & C6*); and

- unless used by a qualified tradesman (*Measures A7 & B7*)

- available on a self-service basis to the consumers (*Measure C2*).

Analysis of Targeted Restrictions on Industrial and Professional Uses of DCM-based Paint Strippers

The effectiveness of the targeted restrictions that were presented above can be summarised as follows (this discussion considers industrial and professional uses together):

<u>Restriction on use unless used in Strictly Controlled Conditions (Measures A2 & B2)</u>

Advantages: it would deal with the misuse of DCM-based paint strippers due to inadequate ventilation, use of inappropriate respiratory protection equipment, when is needed, use of incorrect type of gloves and accidents involving employees being kill in or around dipping tanks.

Drawbacks: it may require changes in the workplace (for industrial uses) which may not be straightforward to implement, for instance, the creation of a separate drying area when a dipping tank is in operation. Users will still need to monitor airborne concentrations to ensure that ventilation is "adequate" and to judge whether independent air supply respirators need to be used or not. In professional uses, this problem would be more prominent. Users would need to change their habits to comply with the provisions of this restriction. Resistance to change could affect the effectiveness of the measure, especially in professional uses where supervision may be scarcer than for industrial uses. The fact that new PPE or engineering controls may be present cannot provide a 100% guarantee that the users will use it properly and effectively.

<u>Restriction on Use in Enclosed Spaces (Measures A3 & B3)</u>

Advantages: such a restriction would address effectively the risks from use of DCM-based paint strippers in spaces such as rooms, basements, industrial installations where no natural ventilation can be ensured (i.e. lack of doors, windows, etc. which can be opened to increase the circulation of air and reduce the airborne concentration of DCM).

Drawbacks: it does not target several other types of conditions under which adverse effects from exposure to DCM may manifest. For instance, it would not address the issue of inadequate ventilation in its entirety (inadequate ventilation is not always a result of working in an enclosed space, it may occur elsewhere too). It also does not address the problems associated with the use of DCM-based paint strippers in dipping tanks. Also, if such a restriction was implemented correctly, it would lead to the use of alternative paint stripper formulations in enclosed spaces. Not all alternatives may be suitable for use in enclosed spaces and their use could potentially expose the users to new risks.

<u>Restriction on Use unless Appropriate PPE is used (Measures A4 & B4)</u>

Advantages: this measure would address issues of misuse due to the use of incorrect PPE. Theoretically, users wearing the appropriate equipment at all times would be sufficiently protected.

Drawbacks: it could be considered as a cut-down version of Measures A2 & B2. It could promote over-reliance on PPE and would contravene the spirit of existing workers legislation which places more emphasis on substitution and engineering controls before considering PPE. If implemented in a sweeping manner, it could require users to use respiratory protection equipment at all times, although adequate ventilation may be in place. Again, as for Measures A4 & B4, users may resist a change in their working habits and this would affect the effectiveness of the measure.

<u>Restriction on Use unless Weight Loss by Evaporation is no more than 2% or 1.85% by Weight of the Loss by Evaporation for Pure DCM (Measures A5 & B5)</u>

Advantages: use of vapour retardants may reduce exposure (by reducing the rate of release of vapours).

Drawbacks: the extent to which vapour retardants contribute to reduced emissions and exposure to DCM is unclear. Moreover, vapour retardants already find widespread use. The discussion in Sections D3.6 and D3.7 (Annex D) goes in detail to show that the use of vapour retardants cannot be considered an effective risk reduction measure on its own.

<u>Restriction on Use unless Products are Supplied in Containers of Volume Smaller than a Certain Threshold (Measures A6 & B6)</u>

Advantages: this measure would be effective in preventing exposure from spillages and by restricting access to DCM-based paint strippers more generally

Drawbacks: spillages are not one of the main concerns or reasons behind accidents resulting from industrial or professional use of these products. A restriction on size will not address or alter the way the product is used by the user.

When discussing the size of container and how this may impact upon the exposure of the user to DCM and the associated risks the following may be considered:

- the size of the container cannot be the same for all broad categories of use, industrial, professional and consumer because these types of users have different requirements, and use patterns: a 0.5L container may be suitable for a consumer who needs to remove the paint from a window frame but not for an industrial use which involves the use of a dipping tank with a capacity of several cubic metres or the stripping of paint from large surfaces (e.g. aircraft, vehicle, large furniture, etc.);

- similarly, companies involved in professional uses may consume a few thousand litres per year (as indicated from consultation) and containers of 5 or 25 litres may be more appropriate; therefore,

- a possible restriction on the size to 1 or 0.5 litre is of relevance to the consumer only.

<u>Restriction on Use unless used by a Qualified Licensed User (Measures A7 & B7)</u>

For a user to qualify as a licensed user, he needs to undergo training that will provide him with the necessary information and knowledge that will be the core of his competence. Therefore, this measure will be combined with the provision of information, advice and training (Measures A9 & B9) and will be discussed in more detail later in this Section.

Analysis of Targeted Restrictions on Consumer Uses of DCM-based Paint Strippers

The effectiveness of the targeted restrictions for consumers that were presented above can be summarised as follows:

Restriction on Self-service sales of DCM-based Paint Strippers (Measure C2)

Advantages: could assist in providing additional information to consumer prior to using the product at home. It could in theory separate the consumer market from the professional market.

Drawbacks: there is uncertainty regarding the implementation and enforcement of a prohibition on self-service sale. The results obtained from countries where similar restrictive measures have been put in place indicate that the results cannot be guaranteed at present. While, there is currently no information on the French experience with this system, German experience suggests that a significant portion of retailers may be implementing the law loosely or be involved in illegal sales. From a risk reduction point of view, making it more difficult to obtain the product may reduce its usage but will not necessarily improve the way it is used.

Restriction on Use in Enclosed Spaces (Measure C3)

Advantages: similar to those for industrial and professional uses (addresses risks from used in closed rooms, basements, etc.)

Drawbacks: similar to those for industrial and professional uses (does not address ventilation issues as a whole[49], neither does it address issues of hand and respiratory protection; alternatives may also pose risks in enclosed spaces). There is also uncertainty associated with consumer response to a prohibition such as this. In practice, it is unlikely that consumers will pay much attention to such a prohibition especially when there is no mechanism for enforcement at Member State level. A consumer cannot also be expected or guaranteed to recognise and act upon 'new' information provided (on an old product that has been on the market for years).

Restriction on Sales unless sold along with Appropriate Personal Protective Equipment (Measure C4)

Advantages: this measure would address issues of misuse due to the use of incorrect PPE. Theoretically, consumers wearing the appropriate equipment at all times would be sufficiently protected.

Drawbacks: consumers are very unlikely to accept such a measure as it would make the use of DCM-based paint stripper very uncomfortable (apart from extremely costly). Even if the sale of appropriate PPE alongside the paint stripper was mandatory, the

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49 As SCHER (2005) noted, even with ventilation rates above what is considered 'average' exposure levels may be unacceptably high.

authorities would have no way of checking whether the PPE is actually used by consumers.

Restriction on Use unless Weight Loss by Evaporation is no more than 2% or 1.85% by Weight of the Loss by Evaporation for Pure DCM (Measure C5)

Advantages: use of vapour retardants indeed reduces exposure (by reducing the rate of release of vapours).

Drawbacks: the extent to which vapour retardants contribute to reduced emissions and exposure to DCM is unclear. Moreover, vapour retardants already find wide use and in consumer products their presence is the norm. The discussion in Sections D3.6 and D3.7 (Annex D) goes in detail to show that the use of vapour retardants cannot be considered an effective risk reduction measure on its own.

Restriction on Use unless Products are Supplied in Containers of Volume smaller than a Certain Threshold (Measure C6)

Advantages: this measure would be effective in preventing exposure from spillages and would also effectively address risks from inhalation of DCM during idle periods or accidental exposure of children.

Drawbacks: spillages are not one of the main concerns or reasons behind accidents resulting from industrial or professional use of these products. Apart from container size, there are also other factors that may influence exposure such as:

- the competence and actions of the user; and
- the consumer's stripping needs, i.e. the consumer will purchase a quantity appropriate for the job at hand even if this means buying multiple small containers (if only small containers are available at the retail outlet).

According to the results of the ETVAREAD study (and as commented by SCHER), unacceptable risks may result even when only 0.35L is used for paint stripping (under the conditions of the ETVAREAD testing).

Box 7.2 presents a comparison of the advantages of larger and smaller containers for consumer use.

Box 7.2: Key Features of Potential Restrictions According to Container Size (Measure A6, B6, C6)

These two sizes have both their advantages and disadvantages. These may be summarised as follows:

Advantages of a larger container

- The container size can address risks associated with the initial transfer/decanting issue but does not address risks associated with the way the products is actually being used by the operator (for example, decanting);
- smaller containers could mean that more than one containers may be open at any one time with the result of higher evaporation of DCM;
- the design of the container with a spill-proof mechanism or narrow neck can prevent accidental spillage without the need for a restriction on the container size;
- a large container with a small neck is probably better than a small container with a wide neck;
- the release volume from a spillage is not necessarily related to the container capacity;
- large containers have a smaller impact on the environment because they create less packaging waste and lower emissions from transporting them;
- large containers are more economical;
- smaller containers could mean that the user would have to shake the container to fully empty the vessel which could result in accidental spillage on unprotected skin;
- larger containers, being heavier, are far less likely to be knocked over than smaller ones;
- larger containers can accommodate larger labels and thus carry more advisory and safety information; and
- assuming the volumes sold by retailers stayed the same, the number of smaller containers would increase and the space required for storage would be difficult.

Advantages of a smaller container

- A smaller container means that the quantity of DCM available is smaller and therefore the quantity that may be released and potentially inhaled is smaller;
- when one container is used, a smaller container results in smaller evaporation and exposure of the operator;
- a smaller container may result in lower exposures in the event of an unattended spillage which results in the entire contents of the container to be spilt; and
- in mixtures of DCM/methanol, DCM being more volatile evaporates and consequently the percentage of methanol increases gradually in the paint stripper. As methanol is flammable, there is a composition for which the blend becomes flammable (the DCM content is too small to extinguish the flammability of methanol). So minimising the container size, there is a delay in the evaporation and the product can be used quicker before the mixture becomes flammable (below 78% of DCM, the blend becomes flammable).

In general, the TGD (EC, 1998) notes that exposure/releases from consumer and domestic use are, in general, unsupervised. In commenting on the effectiveness of risk reduction measures and the enforcement issues, the TGD indicates that the introduction of controls at an earlier stage will often be the most effective way to reduce risks in these cases. Therefore, measures that control the access of consumers to the product may be more important than those aimed at changing the way the consumer uses the product.

7.3.3 Effectiveness of Non-restrictive Measures

Non-restrictive Measures for Industrial and Professional Uses

Establishment of a Community-wide Occupational Exposure Limit for DCM (Measures A8 & B8)

While, in theory, this measure could help achieve the required reductions in exposure when used in the framework of existing legislation; in practice, observing OELs, especially in 'open' applications (such as removal of paint from external building walls), is problematic. It is also very difficult, in practice, for those involved in professional uses (working outdoors or requiring continuous movement from one location to another) to adhere to an OEL (or even to conduct measurements to check the levels of exposure). An OEL is a measure more relevant to a stationary industrial installation where reliable measurements may be undertaken, evaluated and acted upon.

More generally, in discussions with users (decorators, graffiti removers), it has emerged that there is not a thorough knowledge of the existing OELs and to date, no user of DCM-based paint stripper has been identified that monitors the airborne concentration of DCM during professional use of DCM-based formulations. Enquiries have actually been received requesting assistance in identifying suitable equipment for such measurements to occur. Where such equipment is actually available on the market, it may well be costly to purchase, particularly by small companies and without such equipment, it is unlikely that professional users can be guaranteed to be taking all necessary measures to protect themselves.

Overall, while it is the case that OELs are already in place, they are not necessarily respected; it is thus unclear whether an EU-wide value would be more effective.

Licensing of Users (Provision of Additional Information, Advice and Training) (Measures A7/9/10/11 & B7/9/10/11)

The aim of licensing of users is to ensure that those using the product have the necessary knowledge to do so while respecting the current legislation and taking all necessary measures to protect themselves. We have envisaged a system of licensing which would aim at the licensing of users involved in both industrial and professional applications. Box 7.3 overleaf presents how such a system would work. A licensing system would have the following advantages and drawbacks:

Advantages: in theory, provision of information and advice could be as effective as most other measures if the user takes the information into account. Also training on action to be taken in emergency situations could prevent people losing their lives in accidents. Communication of new information down the supply chain should also be straightforward which makes this measure quite simple to implement. A licence would provide some guarantee of competence and responsibility of the user i.e. some guarantee that the required risk management measures would be taken to protect the health of workers.

Box 7.3: Key Features of the Licensing of Users through the Provision of Information, Advice and Training – A Possible Licensing Scheme for Users involved in Industrial and Professional Uses
Key features of this system would include: • the **manufacturers of DCM and of DCM-based paint strippers** should fund, develop and deliver accurate, up-to-date and scientifically robust information to their industrial and professional customers with regard to (a) undertaking a proper risk assessment; (b) introducing and operating ventilation systems, where appropriate; (c) choosing, using and disposing PPE (with an emphasis on the necessity for use of fluororubber gloves at all times and of independent air respirators where the conditions of ventilation do not allow for the prevailing national OEL to be adhered to); (d) use of alternative techniques or products, where appropriate; (e) action to be taken in cases of emergency (i.e. how to work with colleagues, assist them if an accident takes place, etc.); and (f) waste disposal; • the **manufacturers of DCM and of DCM-based paint strippers** should fund, organise and deliver training to their customers involved in industrial and professional uses where the aforementioned information will be disseminated, explained and discussed to ensure that enterprises and their employees are adequately prepared for the use of DCM-based paint strippers. Participation in this training should entitle the user to a certificate that proves his attendance and provides a guarantee of his competence. The contents of the training material should also be reflected in the contents of Safety Data Sheets that accompany the supplies to ensure consistency and to allow the user to have a quick reference guide to appropriate actions and practices; • the **industrial and professional user** may only be allowed to use DCM-based paint strippers only if they are licensed (to undertake specific operations) – in line with the training package provided - by the national Competent Authority. The manufacturers of DCM-based paints strippers will not be allowed to supply DCM-based formulations to any industrial or professional user who cannot furnish proof of his licensed status upon request at the time of placing an order; • **national competent authorities** should oversee and approve the training provided and ensure that the information material developed is of the required standard and consistency. They will be responsible for issuing the user licence following an application and submission of the certificate of attendance to the aforementioned training courses. The authorities have the right to request more information from the applicant before granting a licence and the licence is granted entirely at the discretion (and satisfaction) of the authority; and • Applicants may be required to pay an application fee which should be set to be high enough to ensure that: (a) occasional users are discouraged from using DCM-based paint strippers; (b) all users give due consideration to the available safer alternatives and choose one of them to perform their operations, where possible; and (c) the administration costs of setting up a register of users and of the processing of applications and granting of licences are fully covered and create no additional burden to the national authorities.

Drawbacks: it is not clear that providing the information will definitely make the users more responsible. Misuse of DCM-based paint strippers occurs not necessarily due to lack of knowledge but also out of habit, boredom or lack of time (i.e. the risks are assessed quickly and superficially and protection measures are inadequate) or cost considerations (adequate measures, for instance, using the correct type of gloves and replacing them as appropriate would add a considerable additional cost to the budget of companies). We cannot claim that those injured or died in accidents involving DCM-based paint strippers were necessarily not experienced or not knowledgeable or had received poor training before the accident occurred.

Finally, the effectiveness of the training/licensing system would partly depend on the information provided to the participants. Industry would have to develop up to date and scientifically robust training manuals to ensure that the users of these products have adequate protection.

Non-restrictive Measures for Consumer Uses

Provision of Additional Information and Advice on Ventilation and Personal Protective Equipment (Measure C7/8)

Advantages: in theory, it could be effective if the consumer takes the information into account.

Drawbacks: there is limited guarantee that the consumer will read the additional information, comprehend it and act accordingly. If the advice is difficult or costly to follow (for instance, use of types of PPE that are uncomfortable or costly), then it is likely to be ignored. Advice may also difficult to implement (for instance, adequate ventilation may not be ensured if the DIY work is undertaken during the winter and the weather is cold and windows and doors need to remain shut).

7.4 Practicality of Risk Reduction Measures

7.4.1 Introduction

There are three sub-criteria against which the practicality of a risk reduction measure may be assessed:

- *implementability*: the actors involved have to be capable in practise to comply with the measure. To achieve this, the necessary technology, techniques and alternatives should be available and economically feasible within the timeframe set in the restriction;

- *enforceability*: the authorities responsible for enforcement need to be able to check the compliance of relevant actors with the measure. The resources needed for enforcement have to be proportional to the avoided risk; and

- *manageability*: the measure should be manageable (taking into account the characteristics of the sectors concerned, for instance, the number of SMEs) and understandable to affected parties; the means of its implementation should be clear to the actors involved and the enforcement authorities and access to the relevant information should be easy. Furthermore, the level of administrative burden for the actors concerned and for the authorities should be proportional to the risk avoided.

7.4.2 Practicality of Restrictive Measures

Analysis of a Total Ban on Marketing and Use of DCM-based Paint Strippers

For all three use categories, the introduction of a total ban should be a measure straightforward to introduce by the EU and national authorities; only an amendment to the Marketing and Use Directive 76/769/EEC would be required. The procedure is well established with a number of substances already being subject to marketing and use restrictions. For consumers in particular, the ban would simply mean that DCM-based paint stripping products would not be available on the shelves of stores.

The national authorities should already have in place mechanisms of implementation and enforcement of such restrictions and these will be easily understandable to the affected parties (for instance, users would easily understand that the use of formulations that contain DCM, would not be available on the market and should not be used).

Nevertheless, a total ban would indeed force changes to the way users would continue their paint stripping activities; they would probably need to undertake the following actions:

- identify replacement products;
- test the replacement products for their effectiveness in the tasks at hand;
- identify and test other products if the initial choice is not satisfactory; and
- implement any changes in working practices to ensure that the use of the replacement products satisfy their requirements and those of their customers (as applicable)

It is likely that not all alternatives may be suitable; in fact, it may be the case that any one user may need to replace DCM-based paint strippers with more than one alternative formulation: one may work on certain jobs, but not others, etc. In that respect, the effectiveness of the available alternatives would influence the overall practicality of a total ban on DCM-based paint strippers.

It is possible that the use of alternative products might require changes in the equipment used by the users. For example, new tanks may be required for industrial uses, if the replacement paint stripping formulations require, for example, heating (heating is not used with DCM-based formulations due to the low boiling point of the substance).

Furthermore, users may face longer stripping times when using alternative formulations and this will need a change in working patterns and on the organisation of the work (with the associated cost implications for both the user of the paint stripping formulations and his customers).

Practicality issues may also arise for other players in the supply chain. For example, formulators of paint strippers may need to introduce changes to their production facilities or processes before they switch to the production of an alternative. Some formulators have suggested that there may be a need to alter their production facilities to comply with existing safety regulations concerning the storing and use of flammable substances (which may be used as components of the alternative formulations), however, a significant proportion of the formulations appear to already be involved in the manufacture of alternatives and the changes required to the existing plants and installations may not be very complicated. The TNO report (1999) suggests that "*it may even be possible –with minor modifications- to use the same production lines that are now in use for DCM-containing paint removers for the alternatives*".

Analysis of Targeted Restrictions on Industrial and Professional Uses of DCM-based Paint Strippers

The effectiveness of the targeted restrictions that were presented above can be summarised as follows (this discussion considers industrial and professional uses together):

<u>Restriction on use unless used in Strictly Controlled Conditions (Measures A2 & B2)</u>

Advantages: the measure would be implemented under the Marketing and Use Directive (76/769/EEC) without any major problems envisaged. This measure allows for those installations/companies that already operate under "strictly controlled conditions" (as defined in Box 7.1) to continue using DCM-based paint strippers without interruption to their business

Drawbacks: Member States should already have in place mechanisms for enforcing and monitoring the existing legislation and it is unlikely that the introduction of this restriction would result in additional enforcement activity[50]. The existing shortcomings are likely to persist and especially the successful enforcement of such requirements on those involved in highly mobile professional uses will be highly uncertain; the number of SMEs involved in professional (and industrial) uses does not make enforcement an easy task. Users may face disruption to their work if their current practices do not currently comply with the "strictly controlled condition" requirements; for instance, many companies involved in professional uses would need to provide fluororubber gloves to their employees. Industrial installations may face disruption and downtime during the implementation of any new legislation. It may also be the case that certain actions such as the introduction of forced ventilation or the creation of separate drying areas within industrial installations may be unfeasible due to spatial limitations of the installations.

The use of the appropriate PPE may not always be practical or convenient for the users, especially those involved in professional uses for many years using different equipment. For example, the use of independent air supply breathing apparatus by those who in the past have used only visors or filter masks would mean a serious change in habits and possible discomfort and annoyance. Also, the use of fluororubber gloves may provide the best hand protection; however, it is likely to make delicate operations more difficult to perform.

[50] It is reasonable to assume that the relevant authorities in Member States will inform the relevant businesses of any changes in legislation and any new legal and other requirements. They may also issue guidance and circulate this to those likely to be affected by the new legislation. However, it is unlikely that additional monitoring and enforcement activities will take place, apart perhaps from an initial introductory period.

Restriction on Use in Enclosed Spaces (Measures A3 & B3)

Advantages: as above, the measure would be implemented under the Marketing and Use Directive (76/769/EEC) without any major problems envisaged. This measure allows for those companies that already avoid the use of DCM-based paint strippers in enclosed spaces to continue using DCM-based paint strippers without interruption to their business

Drawbacks: apart from the obvious disruption to business and necessary alterations in behaviour/practices by the users described above, this measure may be particularly problematic for users whose nature of work involves extensive work in enclosed spaces. Moreover, there may be potential difficulties in interpreting what the requirements of the restriction or legislation mean (for instance, judging what space is "enclosed"). Evidently, there will again be an issue of practically enforcing such a measure when having to oversee the operations of a large number of SMEs and micro-enterprises involved in highly mobile operations.

Restriction on Use unless Appropriate PPE is used (Measures A4 & B4)

Advantages: the use of PPE should be reasonably straightforward, as long as this equipment is provided by the employers to his employees.

Drawbacks: in practice, there may be a potential difficulty for users of limited knowledge to make informed choices on PPE except where it is clearly set out in national legislation or unless sales of DCM-based paint strippers are only allowed if accompanied by the right equipment.

The issues of changes in habits and practices, comfort and inconvenience mentioned above for measures A2 & B2 will apply here too. It may also be considered that this measure may contradict somehow the spirit of the EU worker protection legislation that requires that engineering controls are given precedence over the use of PPE (this applies to respiratory protection equipment since appropriate gloves should be worn at all times irrespective to the available engineering controls).

Practically speaking, a restriction unless PPE is used may result in cost, inconvenience and longer times required for putting on and removing equipment would reduce its potential uptake by users. Where users obtain the equipment, there is also no guarantee that they will use it properly or replace it as appropriate

Restriction on Use unless Weight Loss by Evaporation is no more than 2% or 1.85% by Weight of the Loss by Evaporation for Pure DCM (Measures A5 & B5)

Advantages: products that contain vapour retardants are already available on the market and are widely used, especially in professional uses.

Drawbacks: some industrial uses (dipping tanks and cleaning operations) require that the formulations do not contain paraffin waxes, hence any requirement for compulsory use of vapour retardants would cause problems unless provisions are made in the new legislation for such applications. It is unclear what the percentage of weight loss should be as there have been differing suggestions on its value. Moreover, the currently known analytical method for the calculation of the weight loss is not necessarily reproducible and does not appear to take into account of the way each user uses the product. Sections D3.6 and D3.7 (Annex D) discuss the practical issues of using this weight loss as a risk reduction measure.

Restriction on Use unless Products are Supplied in Containers of Volume smaller than a Certain Threshold (Measures A6 & B6)

Advantages: the formulators would probably have little trouble implementing such as measure and the authorities would relatively easily enforce it.

Drawbacks: a restriction of the size to the levels of 500 ml or 1,000 ml would be completely unrealistic for industrial and professional uses in which considerable quantities of paint strippers are required (for example, in dipping tanks). The time that would be required to use multiple containers, the amount of waste generated and the potential for multiple exposure (for instance, if the containers are accidentally tipped over) make this measure particularly unattractive.

Restriction on Use unless used by a Qualified Licensed User (Measures A7 & B7)

As said above under the discussion on "Effectiveness", for a user to qualify as a licensed user, he needs to undergo training that will provide him with the necessary information and knowledge that will be the core of his competence. This measure is combined with the provision of information, advice and training (Measures A9 & B9) and will be discussed in more detail later in this Section.

Analysis of Targeted Restrictions on Consumer Uses of DCM-based Paint Strippers

Restriction on Self-service sales of DCM-based Paint Strippers (Measure C2)

Advantages: once this system is set up, it should normally be easy to administer.

Drawbacks: it is unclear whether a provision of mandatory instructions by a qualified salesperson would be a workable solution. Apart from being difficult to enforce, it is often the case that paint strippers are sold by large retail outlets where self-service is the norm in order for running costs (and prices) to be kept low. In this environment, there is also a high turnover of salespersons (many of them seasonal or on a part-time basis), making training difficult. On the other hand, when the retail store is a small one (say, with 2-3 employees), it may again be impractical to expect that one these few employees would be expected to act as a specialist providing (mandatory) advice to consumers on the use of a single product.

Several Competent Authorities have expressed concerns about the workability of such a system (but at least one Competent Authority of a Member State believes that this measure would be implementable). Industry consultees have also voiced their concern on this recommendation; it has been suggested that it bears little relation to the reality inside a DIY retail outlet. One retailer (that runs a large number of DIY stores) emphasised that the main challenge for the DIY retailer would be the provision of suitable storage for the prohibited self-service. The installation of secure cabinets or similar facilities would be complicated and costly and it is unclear who would train the salespersons and what type of training would be required. Another retailer indicated that prohibition on self-service sales will effectively legislate against high street DIY retailers stocking any size of DCM based paint strippers as they have no provision for a "behind the counter" service.

Overall, while a restricted sales system should be easy to administer (after it has been set up), setting it up may prove to be the difficult and challenging task. Significant levels of administrative burden may be introduced, such as significant changes to spatial layout and book-keeping of stores and shops and in practice, the standard of service delivered will also vary from store to store. The difficulty in differentiating between consumers and professionals at the point of purchase means that this measure may require the development of further (regulatory) guidance or legislation – and may also discriminate against or inconvenience small-scale professionals who purchase their paint strippers alongside the consumer.

Restriction on Use in Enclosed Spaces (Measure C3)

Advantages: instructions on the products available to the consumer would be easily incorporated; however, advice against the use of DCM-based paint strippers in enclosed spaces (i.e. without adequate ventilation) is generally provided on the products currently on the market.

Drawbacks: there may be potential difficulties in interpreting the requirements of the restriction on use in enclosed spaces; for instance, judging what space is "enclosed". This measure may be practically unenforceable when the consumer need to use the paint stripper indoors in a room without windows (for example, a basement) or when the weather is such that opening windows and doors to increase ventilation is not an option (for instance, in winter or in colder climates in Northern Europe). There is also no means of monitoring consumer behaviour in the home and, as such, the practicality of this measure is questionable.

Restriction on Sales unless sold along with Appropriate Personal Protective Equipment (Measure C4)

Advantages: the procedure for introducing marketing and us restrictions is well established, however, other than that no further advantages are envisaged for this measure.

Drawbacks: the uncertainty associated with consumer behaviour means that a retailer may guarantee that the consumer has bought the relevant PPE but cannot guarantee that the consumer will actually use it[51]. Even if the consumer intends to use the PPE, some types of this equipment are not realistically suitable for home use.

Restriction on Use unless Weight Loss by Evaporation is no more than 2% or 1.85% by Weight of the Loss by Evaporation for Pure DCM (Measure C5)

Advantages: generally, the products available on the market for consumer use contain vapour retardants; hence, this measure would cause little inconvenience to all actors in the supply chain.

Drawbacks: as discussed further above under the industrial and professional uses, it is unclear what the percentage of weight loss should be as there have been differing suggestions on its value. Moreover, the currently known analytical method for the calculation of the weight loss is not necessarily reproducible and does not appear to take into account the way each user uses the product. Sections D3.6 and D3.7 (Annex D) discuss the practical issues of using this weight loss as a risk reduction measure.

Restriction on Use unless Products are Supplied in Containers of Volume Smaller than a Certain Threshold (Measure C6)

Advantages: a quick market research undertaken in England confirms that DCM-based paint strippers may be found on the shelves of DIY stores in sizes of 500 ml, 1,000 ml and upwards. Therefore, any such measure will not cause insurmountable problems to formulators.

Drawbacks: some formulators may need to alter their packaging (which could mean that old stock may need to be disposed of). Small containers would be less economical and would result in added packaging and waste compliance costs for a given amount of paint stripper. A manufacturer has indicated that, from a production perspective, as they did not have automatic filling lines, 1 litre packs would slow down the filling operations. They, however, did not anticipate any problems from a commercial point of view. On the other hand, consumers may need to purchase multiple containers and this could cause some inconvenience.

7.4.3 Practicality of Non-restrictive Measures

Non-restrictive Measures for Industrial and Professional Uses

Establishment of a Community-wide Occupational Exposure Limit for DCM (Measures A8 & B8)

Advantages: in practice, mechanisms and legislative frameworks for introducing OELs are already in place across EU Member States. During discussions with officials at the

[51] Also, under this measure, the authorities would effectively make the retailers responsible for the behaviour of the consumers (by requiring them to sell products only when sold with appropriate PPE) well after the consumer has left the store.

Directorate-General Employment of the Commission (EC, 2007) suggest that the Scientific Committee on OELs (SCOEL) is currently looking into the establishment and introduction of an EU-wide OEL (whether this would be an indicative or a binding limit is currently unknown). In several Member States, national OELs are currently in place, therefore, many of the companies involved should in theory be familiar with the technicalities of complying with an OEL.

Drawbacks: as with existing OEL, there is the likelihood for poor implementation. This reduces the practicality of this measure with regards to its ability to deliver further risk reduction. Based on the analysis in the previous Sections, it is considered that an OEL on its own would be inadequate for addressing the risks from DCM-based paint strippers for two main reasons:

- an EU-wide OEL is unlikely to result in greater compliance, fewer DCM-related incidents and/or increased human health protection compared with the current situation. As noted earlier, national OELs are currently in place (including the countries for which fatal accident data are available); hence, the key issue relates to how to improve user adherence to the OEL (where the adherence, rather than the 'limit' chosen, is the main limiting factor for the effectiveness of this measure); and

- an EU-wide OEL is unlikely to be effectively monitored, especially for the numerous SMEs. While OELs are useful tools for the control of exposure in large industrial facilities (which are monitored and well-regulated and where enterprises have the financial means and knowledge to install and use monitoring equipment), there are a large number of SMEs that undertake paint stripping operations (for example, small furniture workshops) and the knowledge of the employers and/or employees of the relevance (and subsequent enforcement) of OELs may be limited. Where professional uses are involved, adherence to OELs is even more patchy due to the lack of monitoring equipment and the mobile nature of many operations. Obviously, the presence of numerous SMEs (and micro-enterprises) makes any national enforcement activity by Competent Authorities very difficult and onerous.

<u>Licensing of Users (Provision of Additional Information, Advice and Training) (Measures A7/9/10/11 & B7/9/10/11)</u>

Advantages: this measure would in theory have fewer implications than an outright ban on the industrial and/or professional uses of DCM-based paint strippers. Also, it aims at influencing the long-term behaviour of the user so that the use of DCM-based paint strippers under the appropriate conditions is the result of conscious choice rather than the result of authority enforcement or fear of a penalty.

Industry would be responsible for organising training courses, disseminating information, testing and licensing of those intending to be employed in a paint stripping business. While the authorities would be overseeing the operation of this system, industry would play the key functions. The currently available literature would be used in the training but only after updating it and adapting it to take into account the engineering controls and PPE required when paint stripping with DCM-based formulations is undertaken.

Drawbacks: a system such as the one described in Box 7.3 could have some practical implications:

- it is unclear how the training would be organised and what exactly would the role of different stakeholders be;

- an issue of mutual recognition of licences among Member States would be likely to arise (mutual recognition would be required to ensure a common understanding of the term "qualified and licensed user" across the EU);

- companies could face problems in meeting customer requirements if they needed to spend time identifying and hiring workers who hold current licences;

- Competent Authorities may generally be unable and/or reluctant to be involved in participating in such as scheme; the current legislative framework requires that companies (employers) are responsible for assessing and taking the necessary action to address risks to their employees. Therefore, any risk reduction measure which may require additional input by the authorities may place an additional burden on their available resources;

- the fact that a worker has a licence may prove that he/she has undertaken the necessary course but it would not provide a 100% guarantee that the worker will indeed use his knowledge in making the correct choices. Fundamentally, any guidance cannot guarantee the required level of exposure reduction because its success relies on the willingness of the user to comply with the guidance. In general, the provision of more information on hazards/risks and relevant training of personnel are measures which are effective when complementing other risk reduction measures. Any such guidance may thus be of more relevance when used as documentation of the aims and targets of other more binding measures, such as legislation or as a walk-through for individual companies in choosing and implementing new technologies that will allow them to comply with new legislation;

- many employees would still work unsupervised (especially when small enterprises are involved in professional uses), increasing the likelihood of standards not being adhered to;

- the existing literature provided for by the formulators need to be adapted so that users/employers would receive the appropriate information and training over and above what is currently provided. It could be difficult to co-ordinate the training material in different Member States; and

- the presence of a large number of SMEs (which are possibly not represented by a national or European trade association) would further complicate the co-ordination of such a training system.

Non-restrictive Measures for Consumer Uses

Provision of Additional Information and Advice on Ventilation and Personal Protective Equipment (Measure C7/8)

Advantages: the addition of further detail in the literature that accompanies chemical products should be straightforward.

Drawbacks: information is generally already provided with the products available to consumers; its potential revision would be likely to result in "old" products being accompanied by "new" information which may not be given adequate attention.

As is generally the case for occupational users of DCM-based paint strippers, additional information and guidance can only appeal for voluntary action. The authorities would not be able to take enforcement action.

Finally, it is unclear under which legislative (or administrative) framework this measure may be implemented.

7.5 Monitorability of Possible Risk Reduction Measures

7.5.1 Introduction

There are two sub-criteria against which the monitorability of a risk reduction measure may be assessed:

- *ease of monitoring*: the monitoring of a suitable measure should be easy to set up and administer and its cost and administrative burden should be proportional to the levels of use of the chemical and the number of actors involved; and

- *availability of monitoring mechanisms*: effective monitoring mechanisms should be in place to monitor both use and releases, and the implementation and success of the measure. Monitoring should be capable of providing the necessary guarantees that Industry is complying and that the measure is meeting its original objectives across the Community and within the required timeframe. Measures capable of utilising existing monitoring mechanisms may have a relative advantage over measures that require new ones.

7.5.2 Monitorability of Restrictive Measures

Restrictions on Industrial and Professional Uses of DCM-based Paint Strippers

Overall, the restrictions being considered will employ the existing monitoring networks that have been established by Member States Competent Authorities for such purposes, as well as those which may already be taking place due to companies' obligations under existing regulatory frameworks. Any additional requirements may be related to setting up programmes (e.g. administrative and monitoring) specific to DCM-based paint strippers (depending on the detail of how Member States implement any restriction(s)). The presence of a large number of SMEs also complicates monitoring activities, especially with regard to professional uses. It should be noted that the introduction of new legislation on DCM-based paint strippers does not automatically mean that Member State Competent Authorities will increase their monitoring activities that are focused on the paint stripping sector[52]; after all, the authorities do not have infinite resources or personnel and need to prioritise their workload.

The following paragraphs provide some additional detail for each of the measures under consideration.

Total Prohibition on all Uses of DCM-based Paint Strippers (Measures A1 & B1)

This measure should be the easiest to enforce and monitor and Member States already have experience and mechanisms for monitoring.

However, the nature of monitoring will be different for industrial and professional uses. Industrial uses take place in permanent stationary technical units which inspectors may in theory visit and establish whether legislation is adhered upon or not. With professional uses this is not necessarily the case.

An issue may also arise if one category of uses is prohibited but not the other. Then, it would be important to be able to distinguish between the users involved in industrial or professional uses. A single user may be involved in both professional and industrial uses and the authorities should have in place or introduce mechanisms for establishing whether the DCM-based paint strippers are used in approved applications or not.

Total Prohibition on all Uses of DCM-based Paint Strippers unless used in Strictly Controlled Conditions (Measures A2 & B2)

Member States should have in place the necessary mechanisms for monitoring the conditions of use in permanent stationary technical units.

However, monitoring of adherence to strictly controlled conditions would be very demanding and effectively limited for professional uses due to the mobile nature and the small scale of operations of those involved in them.

Prohibition use of DCM-based Paint Strippers in Enclosed Spaces (Measures A3 & B3)

As above for Measures A2 & B2, monitoring enforcement for users undertaking industrial uses will be relatively straightforward (although it cannot be claimed that 100% of the companies involved will be under constant supervision by the authorities), while for users involved in professional uses, monitoring will be very complicated.

52 Naturally, the authorities may intensify their activities and disseminate information and guidance at the start of the implementation of new legislation on DCM-based paint strippers.

Any lack of clarity in the definition of "enclosed spaces" may also impact upon monitoring of such a measure.

Total Prohibition on all Uses of DCM-based Paint Strippers unless used with Appropriate PPE (Measures A4 & B4)

As above for Measures A2 & B2, monitoring of industrial uses will be straightforward.

For professional uses, the mobile nature of work and the lack of supervision by someone with expertise in Health and Safety issues could possibly mean that poor implementation may not be properly monitored and acted upon.

Total Prohibition on all Uses of DCM-based Paint Strippers unless Vapour Retardants are used to the effect that the % Weight Loss by Evaporation is not more than 2% or 1.85% by Weight of the Loss by Evaporation for Pure DCM (Measures A5 & B5)

In theory, mechanisms exist at the national level for the implementation and monitoring of restrictions on the composition of preparations placed on the market in Member States. However, it would be difficult for authorities to ensure that the presence of vapour retardant indeed reduces the weight loss below a specified limit not least because a standardised reproducible test of measuring weight loss does not appear to be currently available (SCHER (2005) has made some important comments on the reproducibility of results with the most well known test method – see Section D3.6.3 in Annex D).

Prohibition on Sales of DCM-based Paint Strippers unless Products are Supplied in Containers of Volume Smaller than a Certain Threshold (possible thresholds: 5,000 ml or 1,000 ml) (Measures A6 & B6)

Monitoring of this measure should be straightforward for both industrial and professional uses.

Prohibition on Use of DCM-based Paint Strippers unless Used by a Qualified and Licensed User (Measures A7 & B7)

Monitoring mechanisms are not currently in place per se. Therefore, some significant effort may also be required at the start of the implementation period; however, the burden for this should be carried by industry and is not expected to be excessively onerous once put in place.

Restrictions on Consumer Uses of DCM-based Paint Strippers

The following paragraphs provide some additional detail for each of the measures under consideration.

Total prohibition on all consumer uses of DCM-based paint strippers (Measure C1)

The monitoring of this measure will be easy and straightforward and mechanisms should already be in place in Member States.

Prohibition on self-service sale of DCM-based paint strippers (Measure C2)

There will be an initial period during which the monitoring arrangements will need to be agreed. After implementation, the monitorability of this measure will depend on the number of outlets selling DCM-based paint strippers in each Member State and the nature of these outlets (i.e. DIY store chains vs. independent retailers). Recent reports on German media suggest that such systems may be abused.

A potential problem, however, arises from the current non-separation of the markets for consumers and professionals. In this regard, an additional administrative burden may be incurred if retailers (who will be monitored by the authorities) are required to register sales and purchaser details.

Prohibition on Consumer Use of DCM-based Paint Strippers in Enclosed Spaces (for example, basements, small rooms without windows, etc.) (Measure C3)

It is impossible to monitor the actions of consumers in their households.

Prohibition on Sales of DCM-based Paint Strippers unless sold along with Appropriate PPE (Measure C4)

This measure would place a huge burden on authorities in monitoring compliance. Also, issues of liability may arise since this measure effectively places on retailers the responsibility for the consumers' behaviour when using the DCM-based paint strippers.

It is impossible to comprehensively monitor the actions and behaviour of consumers during DIY applications.

Total prohibition on sales of DCM-based paint strippers to consumers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM (Measure C5)

As above for the monitorability of the measure for industrial and professional uses.

Prohibition on sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (500 ml or 1,000 ml) (Measure C6)

Monitoring of this measure should be straightforward; however, problems may arise if the authorities intend to discourage or prevent the consumers from purchasing multiple containers.

7.5.3 Monitorability of Non-restrictive Measures

Non-restrictive Measures for Industrial and Professional Uses

Establishment of a Community-wide Occupational Exposure Limit for DCM (Measures A8 & B8*)*

Existing monitoring frameworks are in place for monitoring OELs, however, the existing inadequacies of the current national monitoring and enforcement systems will apply. As explained earlier in this report, monitoring among users involved in professional applications will be (and is at present) much more complicated than for industrial uses.

Licensing of Users (Provision of Additional Information, Advice and Training) (Measures A7/9/10/11 & B7/9/10/11)

Monitoring of any licensing system will primarily be the responsibility of industry, although Member State authorities would probably be overseeing it. It may be reasonably simple for industry to monitor the functioning of the licensing system (production of training material, training of employees and provision of training), however, it will be considerably more complex (and in practice available) to monitor the actions of the licensed workers (i.e. monitoring the success of the system would be much more difficult).

Non-restrictive Measures for Consumer Uses

Provision of Additional Information and Advice on Ventilation and Personal Protective Equipment (Measure C7/8)

The additional information would either be provided as part of the information currently supplied to consumers (warnings on the package or accompanying leaflets) or additional leaflets may be devised and attached to the DCM-based products. Although, it would be relatively straightforward to monitor whether the correct information is indeed provided to consumers alongside the products, it would be close to impossible to monitor whether the (additional) information is actually read, understood and acted upon accordingly.

7.6 Conclusions

Table 7.1 summarises the above discussion on the assessment of the aforementioned potential risk reduction measures against the three key assessment criteria of effectiveness, practicality and monitorability. Within the table, measures that are likely to perform poorly are eliminated from further consideration.

In Section 8, we discuss the likely economic impacts of restrictions on different actors in the supply chain. The combination of the assessment of the potential risk reduction measures with their likely economic implications will assist us in identifying the most suitable measures for risk management.

Table 7.1: Summary of the Effectiveness, Practicality, Economic Impact and Monitorability of Measures Considered

Risk Reduction Measure	Effectiveness	Practicality	Monitorability	Overall Summary
Industrial & Professional Uses				
A/B1. Total prohibition on all *industrial* and *professional* uses of DCM-based paint strippers	✓(/?)	?/✗	✓	*Possible RR option*
A/B2. Total prohibition on all *industrial* and *professional* uses of DCM-based paint strippers unless used in strictly controlled conditions	✓/?	✓/?	✓	*Possible RR option*
A/B3. Prohibition on *industrial* and *professional* use of DCM-based paint strippers in enclosed spaces	✓/?	?/✗	?/✗	*Not a suitable RR option*
A/B4. Total prohibition on all *industrial* and *professional* uses of DCM-based paint strippers unless used with appropriate PPE	✓/?	?/✓	✓/?	*Possible RR option*
A/B5. Total prohibition on all *industrial* and *professional* uses of DCM-based paint strippers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM	✗	✓	?/✗	*Not a suitable RR option*
A/B6. Prohibition on sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (possible thresholds: 5,000 ml or 1,000 ml)	✗	✗	✓	*Not a suitable RR option*
A/B8. Establishment of a Community-wide occupational exposure limit for DCM	✗	?/✗	?	*Not a suitable RR option*
A/B7/9/10/11. Licensing of users (provision of additional information, advice and training)	✓/?	✗	✓/?	*Not a suitable RR option*
Consumer Uses				
C1. Total prohibition on all consumer uses of DCM-based paint strippers	✓	✓	✓	*Possible RR option*
C2. Prohibition on self-service sale of DCM-based paint strippers	?	?	✓/?	*Not a suitable RR option*
C3. Prohibition on consumer use of DCM-based paint strippers in enclosed spaces (e.g. basements)	✗	✗	✗	*Not a suitable RR option*
C4. Prohibition on sales of DCM-based paint strippers unless sold along with appropriate PPE	✓	✓/?	✓/?	*Possible RR option*
C5. Total prohibition on sales of DCM-based paint strippers to consumers unless vapour retardants are used to the effect that the % weight loss by evaporation is not more than 2% or 1.85% by weight of the loss by evaporation for pure DCM	✗	✓	?/✗	*Not a suitable RR option*
C6. Prohibition on sales of DCM-based paint strippers unless products are supplied in containers of volume smaller than a certain threshold (500 ml or 1,000 ml)	✗	✓	✓	*Not a suitable RR option*
C7. Provision of additional information and advice on using DCM-based paint strippers under conditions of adequate ventilation and appropriate PPE	✗	?/✗	?/✗	*Not a suitable RR option*

(✓) = Acceptable (✗) = Not acceptable (?) = Uncertain outcome (RR) = Risk reduction
Measures are eliminated from further consideration if: (a) they appear to have 'straight' ***✗ marks (i.e. they are certain to fail one or more of the three assessment criteria, especially effectiveness);*** *or (b) they appear to be uncertain or unsuitable (?/✗) under two or three assessment criteria. These measures are shaded.*

8. ECONOMIC IMPACT OF POTENTIAL RESTRICTIONS

8.1 Introduction

The TGD (EC, 1998) specifies that the economic impact of any possible further risk reduction measures on producers, processors (or formulators), users and other relevant parties should be examined in developing an RRS. While the level of detail of such an assessment would depend significantly on the amount of information provided by industry, it should aim to provide a good basis for decision-making.

This Section assesses the economic impact of potential restrictions on the marketing and use of DCM-based paint strippers on:

- **manufacturers of DCM** (Section 8.2);
- **manufacturers of DCM-based paint strippers** (Section 8.3);
- **those involved in various uses** (industrial, professional and consumer) of DCM-based paint strippers (Sections 8.4 to 8.6); and
- **other stakeholders/third parties** (e.g. pharmaceutical and recycling companies) who may be impacted indirectly (Section 8.7).

A summary of the costs and benefits to all parties is provided in Section 8.8.

8.2 Impact of Potential Restrictions on Manufacturers of DCM

8.2.1 Costs to Manufacturers of DCM

Overview of Types of Costs

The types of costs (or negative impacts) which manufacturers of DCM may incur from restrictions on the marketing and use of DCM-based paint strippers include:

- loss of sales to suppliers, distributors and customers;

- an excess supply of DCM (fresh or recycled), which could lead to a decrease in market prices (because the costs of spent DCM destruction are high and recycled DCM will be supplied to other markets putting pressure on prices);

- the costs of possible changes in the production process to minimise DCM production as a co-product in chloroform production (the main product); and

- possible impacts on overall competitiveness in the global market, if impacts on the market for and prices of DCM also affect the associated chlor-alkali products, which are commodity chemicals (having only very low profit margins).

Impact Assessment by the Manufacturers

Three of the six main manufacturers of DCM have presented their own assessments of the potential impacts on their business from a restriction on the marketing and use of DCM-based paint strippers. The individual estimates provided by each of these manufacturers are not given here in order to protect sensitive market information. Instead, we have taken the information provided by these companies and extrapolated it across the EU market based on individual production and value of sales data. If sales of the almost 13,000 tonnes of 'virgin' DCM sold for paint stripper manufacture were lost across the six EU manufacturers, then this would equate to lost sales revenues of around €17 million per annum, as indicated in Tables 8.1 and 8.2 below. Note that this lost revenue relates to the EU market only. It is also important to note that these estimates imply an average price per tonne of DCM of around €1,300 which is higher than figures quoted by users. If a price per tonne of €1,000 is assumed, based on the figures quoted by formulators, then the total value of lost sales would be almost €13 million per annum across the six EU manufacturers. Since there is a very significant variation in the implied cost of DCM per tonne (in the data provided by the manufacturers), we opt to use the €1,000 per tonne figure suggested by a formulator.

Table 8.1: Estimates of the Tonnages Affected by Restrictions on the Marketing and Use of DCM across all Paint Stripping Applications (these figures are approximations)

Lost sales	European market	Global market
Tonnage affected by full marketing and use restrictions	13,000	N/a
Tonnage remaining (i.e. sold for other applications)	98,000	231,000

Table 8.2: Estimates of the Value of Lost Sales and Price Reduction Impacts to Manufacturers from Restrictions on the Marketing and Use of DCM-based Paint Strippers

		€ per tonne DCM			
Decreases in sales volume					
	Use category	European market		Global market*	
		€1,000	€1,300	€1,000	€1,300
Value of lost sales	Industrial	€ 4,330,000	€5,630,000	n/a	n/a
	Professional	€ 4,330,000	€5,630,000	n/a	n/a
	Consumer	€ 4,330,000	€5,630,000	n/a	n/a
	Total	€ 13,000,000	€16,900,000*	n/a	n/a
Losses due to per unit price reduction					
Value of lost revenue by % price drop	10%	€9,800,000	€12,740,000	€23,100,000	€30,030,000
	50%	€49,000,000	€63,700,000	€115,500,000	€150,150,000

* Decreases in sales volume are not applicable to the global market but only to the European market
** Figures may not add up due to rounding errors

In the absence of more information across all Member States, we assume that sales of DCM relating to paint strippers are divided equally among the three use categories, industrial, professional and consumer (33% each).

The figures in Table 8.2 reflect total revenues from the sale of DCM-based paint strippers but not the actual losses in profits (as the estimates are based on the sales price which will be set to cover production and other costs as well as to earn some level of profits). Hence, assuming a profit margin of between 10% and 25%, the actual losses arising from the restriction would range from about €1.3 million to €3.2 million per year. Taking a 33% split between industrial, professional and consumer uses, the cost per use category would be between roughly **€430,000 and €1.1 million per year per use category**.

The three companies also provided estimates of the impact that losing the market for paint strippers would have on the more general market for DCM. All three companies indicated that this would result in a decrease in the per unit sales price of DCM across the remainder of the market. The figures quoted by the companies as to the likely effect on per unit sales price vary significantly, ranging from a 5 to 10% decrease in price at the lowest end to as much as a 50% decrease in price as the highest figure.

It is unclear from the information provided whether these price decreases would be realised only within the EU market or would occur more generally across the global market. As a result, calculations are given in Table 8.2 for both the EU and then for the global market and for both the prices implied by the manufacturers' estimates (€1,300 per tonne DCM) and the price quoted by formulators (€1,000 per tonne DCM). As can be seen from Table 8.2, the potential magnitude of these losses could be significant if the 50% decrease in price is assumed. However, this figure seems unrealistic. Sales data indicate that DCM sales for European paint strippers account for only around 5% of the global sales of DCM and for 12% European sales of DCM (based on data from the six manufacturers). As a result, the lower figure quoted by one of the companies of between 5 and 10% decrease in price is considered to be a more reliable estimate.

The UK Formulators Group (2005) also presents an assessment of the estimated costs of restrictions on the marketing and use of DCM-based paint strippers in relation to professional and consumer uses only (industrial uses are excluded, implying that a total prohibition across the board would have an even higher cost). According to this assessment, the costs for the UK would be as follows:

- ***formulators of DCM-based paint strippers***: the following costs have been suggested:

    - the conversion of existing buildings to the production of alternatives, with this estimated at around €75,000 for companies with modern plants and buildings to €2.8 million for companies with old plants and buildings;
    - €1.3 million and upwards in research, development and marketing costs associated with alternative products;
    - €12 million in the cost of raw materials.

- ***DIY users and tradesmen involved in professional uses***: €240 million due to poorer performance of the alternatives (this was based on trials that the Group undertook);

  - €13.5 million due to increased product prices;
  - for large-scale users involved in professional uses: up to €60 million for local authority contract work due to the need for more applications of products at a higher price;
  - also for large-scale users involved in professional uses: €3 million for heritage refurbishment and conservation work due to the need for more applications of products at a higher price;

It is not clear how these figures have been calculated and what trials the Group has undertaken before reaching the costs mentioned above. These figures are, however, considered to be excessively high and are probably a gross overestimation of the potential costs. For example, they include some double-counting of costs, e.g. in quoting an increase in raw material costs and R&D costs which will also be accounted for in increased product costs to DIY users and those involved in professional uses. The estimates can also be criticised on the following grounds:

- they disregard the existence of alternatives within the portfolios of several of the members of the Group and the likely increase in revenues from selling alternative paint strippers following a restriction on DCM-based paint strippers;

- the assumption on the cost of building new installations for storing flammable chemicals (which are used as alternatives) fails to reflect the fact that many companies (including members of the Group) already offer such alternative formulations and as, such, must have a reasonable capacity for storing flammable materials. Moreover, it is not the case that alternatives must contain flammable components;

- the research, development and marketing costs would not appear to take into account the advantageous position that several companies (in fact the larger among the Group members) would have due to their existing operations involved in the manufacture of alternatives;

- the calculations do not account for the likely reduction of the per unit costs for the raw materials involved in the production of the alternatives due to increases in the economies of scale of their production; and

- the calculations completely disregard the benefits to the companies from any reduction in the need to control emissions of DCM to the environment.

8.2.2 Benefits to Manufacturers of DCM

The main benefits (or positive impacts) which the manufacturers of DCM could realise would result from **sales of alternative 'active ingredients' for paint stripping**

formulations. As a result of any restriction, there will be an increase in the sales of alternative active ingredients used in paint strippers and some of the manufacturers already manufacture certain of the 'active ingredients' examined in Section 5 of this report (as possible alternatives). At least, one manufacturer is known to produce DMSO and is indeed keen to expand its sales into the paint stripper market. The remaining five companies currently manufacture sodium hydroxide and are amongst the largest manufacturers in Europe.

If the production of these alternative substances is already at or near capacity, there may be new opportunities for other manufacturing companies across Europe to meet increases in demand. Similarly, some of the manufacturers of DCM also produce other components of alternative paint striper formulations, with there being a potential parallel increase in sales of these products over time. It is also possible that a restriction on a DCM could result in the development of more innovative solutions and products by the manufacturers of DCM.

8.3 Impact of Potential Restrictions on Manufacturers of DCM-based Paint Strippers

8.3.1 Costs to Manufacturers of DCM-based Paint Strippers

The potential impacts on manufacturers of DCM-based paint strippers from restrictions include:

- loss of sales;
- changes in the costs of raw materials;
- one-off costs from the need to make changes to production facilities, e.g. cost of installing tanks suitable for accommodating flammable liquids;
- one-off costs in developing new packaging and labels, if selling alternative paint strippers); and
- costs relating to research and development, distribution, marketing and overall administration (e.g. preparing new risk assessments, training of personnel in the handling of flammable materials).

In general, very little information was received from manufacturers of DCM-based paint strippers. Some detail has been received from a small number of manufacturers and is presented in an anonymised form in Table 8.3.

Table 8.3: Estimates of Costs of Restrictions on a Number of DCM-based Paint Stripper Manufacturers

Parameter	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I	Company J
SME?	Yes	Yes	No	No	Yes	No	Yes	No	Yes	Yes
Produces alternatives	Yes (5 types)	Yes (1 type)	No	Yes (2 types)	No	No	Yes (2 types)	Yes (4 types)	Yes (1 type)	Yes (5 types)
% turnover from DCM (for the paint stripper part of business)	<<50%	99%	100%	55% (based on tonnage)	100%	100%	85%	97%	65%	85%
Key markets	IND	PROF – CON	CON	PROF – CON	IND – PROF – CON	PROF – CON	IND – PROF – CON	PROF – CON	PROF – CON	IND – PROF
Expected action upon restriction	Sell and promote more non-DCM products.	No major concern if restriction applies to all EU manufac-turers	Probably switch to an alternative	Will focus on developing existing alternatives, esp. benzyl alcohol and DMSO for professional and consumer uses respectively	Switch to alternative for all use categories	Switch to an alternative product, either developed in house or bought in.	For IND: withdraw For PROF: switch to alternatives primarily caustic paste For CON: develop new formulations	Switch to alternatives to meet customer performance and cost demands	Switch to alternative	Switch to alternative
Views on key impacts from a restriction	Increased product cost Lower cost since lower need for storage of volatile solvents Losses from reduced sales		Increased costs (not specified)	Limited impact as already moving out of the market. Company will focus on developing strippers without any major hazard classification		Total loss of PROF and CON market shares envisaged	Severe impacts for PROF and CON uses	Major impacts on profitability	Minor impacts for IND. Extremely serious negative effects for both PROF and CON	Significant impacts

Table 8.3: Estimates of Costs of Restrictions on a Number of DCM-based Paint Stripper Manufacturers

Parameter	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I	Company J
Costs										
Plant and machinery (Capital)	Removal of DCM bulk tank. Mixing vessels would be used for other products					Possible cost increase for storage tanks, pipework, mixing vessels and filling machines	€270,000	€450,000		€500,000 for new machines and services, maybe filling machines
Buildings	None					Unlikely to be a significant cost	€45,000	€300,000		€500,000 more room for flammable products
Legal and other expert fees	None					Unknown	€15,000	?		€10,000-100,000
Training of personnel	Not an issue					Costs may arise from risk assessments, training etc.	€15,000	?		Personnel already trained
Machinery/production downtime	Minimal					Loss of production if the machinery requires any alteration	€52,500	?		?
Product research and development	Minimal		Increased costs			Development work has to be built into ongoing year programmes	€27,000	€150,000		?

Table 8.3: Estimates of Costs of Restrictions on a Number of DCM-based Paint Stripper Manufacturers

Parameter	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I	Company J
Surplus or waste stocks	Ideally we would phase out DCM so we were not left with stock.					Cost of disposing of surplus stocks could be significant where there is no sell through	€0	?		?
Raw material costs and other consumables (energy, water, chemical inputs)	Negligible		Increased costs		€10,000	Raw material costs are very likely to increase. depending on the formulation produced. Other consumables cannot be quantified	€120,000	€7,500,000		DCM costs about €1.00/kg, NMP about €5.00/kg
Waste treatment and disposal	Reduced, DCM waste is currently incinerated.				€0	Unknown	€22,500	?		?
Product development	Already develop non DCM products	€20,000	Increased costs		€0	Development work has to be built into ongoing year programmes	€15,000	?		?

Table 8.3: Estimates of Costs of Restrictions on a Number of DCM-based Paint Stripper Manufacturers

Parameter	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I	Company J
Marketing and regulatory compliance costs	Negligible	€12,000	Increased costs		€0	Cost implication due to new livery, displays, tins etc and ensuring these and the formulation are compliant	€37,500	€300,000		?
Employee protection (personal protective equipment/ ventilation) costs	Reduced				€0	Protection already applies so this is unlikely to be significant	€37,500	?		-
Overall capital costs	***€15,000 (est)***	**-**		***Limited***	***€0***	***Variable cost implication but will very likely be significant***	***€379,500***	***€900,000 - 1,500,000***		***Ca. €1,500,000***
Overall operational costs	***Minimal***	***€32,000 (only for PROF, hence, total cost would be double this)***	***?***	***Limited***	***€10,000 (for each use category, hence, €30,000 in total)***	***Variable cost implication but will very likely be significant***	***€307,500***	***€7,500,000-9,000,000***	***€3,675,000 (€375,000 for R&D, €2,000,000 for new flame-proof equipment, €900,000 for marketing)***	***Ca. €500,000 for raw materials***

Table 8.3: Estimates of Costs of Restrictions on a Number of DCM-based Paint Stripper Manufacturers

Parameter	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I	Company J
Wider Impacts										
Impact on competitiveness	Some loss of business, but it is not a major part of turnover. DCM paint stripper market is contracting and thus its affect on the company would not be substantial	No impact	Not significant The production of DCM-based paint stripper represents a small part of the whole production (<1%)	Positive impact	Negative impact	Negative impact	Negative impact. Replacements for PROF uses may not meet ALL user specifications Increased costs for CON may deter them from using chemical strippers	Negative impact due to significantly increased product costs	Seriously negative impact	Negative impact
Employment impacts	Not likely	No impact	No impact	No impact	1% employment impacts (redundancies)	No impact	Staff would increase to cope with demand for caustic strippers for IND uses	Around 20 or more jobs could be lost if production is moved outside the EU	35% employment impacts (redundancies)	Closing business if cannot switch to alternatives
Impact on innovation	Negligible effect as substitution plans are already in place (in case of any ban)	No effect	No effect	Significantly spur innovation	No impact	No impact	Hinder innovation	Formulators would probably use already known available solvents	Hinder innovation	Hinder innovation

Source: Consultation Responses

Our general conclusions based on the information that has been received from this set of companies are as follows.

- **The majority of companies already have alternative paint strippers in their portfolio**. For instance, while Company A supplies a considerable quantity of DCM-based paint strippers, it has also developed a range of alternatives which actually now represent a higher percentage of their turnover. Company D is in the process of withdrawing from the market and focusing on non-classified ingredients, while Company G is very active in the area of caustic alternatives and expects an increase in business with regard to these.

- **The cost estimates of different companies vary greatly, depending on their overall business strategy** (in particular, their level of 'readiness' to supply alternatives if a restriction on DCM-based products was introduced). A company manufacturing both DCM-based and DCM-free alternatives suggested "*the change to DCM-free products will be cost neutral concerning our production facilities, sales organisation etc. But it is sure that we will lose a part of our turnover because it is not possible to replace DCM by other products with the same stripping effect*". Another company with a strong presence in the DCM-based paint stripper market of its home country noted "*it is impossible to say what the impact would be. It would totally depend on the cost of replacement materials etc…If we could not sell DCM based paint strippers and there was no alternative the loss in revenue to this Company would be approximately €400,000. There would also be loss of revenue for the distributors and retailers of our products*". This cost is equivalent to over €4,400 per tonne of DCM-based paint stripper produced in 2005. In terms of withdrawal from the market, this is an option considered by companies with limited sales. On this point, one company noted "*…given the volume of paint remover sold by our company, this type of product is not a priority when it comes to dedicating R&D time and money*".

- **The majority of companies see no potential impact on employment levels**, however, for some this depends on whether a suitable alternative could be developed. One major manufacturer indicates (without providing any evidence) that its operations could, in theory, be relocated to a non-EU destination following a restriction on DCM. However, this company currently has a range of alternatives in its product portfolio (already achieving good sales in the market). While the success of any company in switching from DCM to alternatives cannot be predicted, it is reasonable to expect that those companies with pre-existing alternative products in their portfolio may have a relative competitive advantage.

- **There is a mixed reaction on whether any potential restriction may spur or hinder innovation**. For instance, Company A believes that alternatives are already available and additional alternatives may not be developed following a potential restriction. Although Company I has indicated a likely investment of €375,000 in research and development, it believes that a restriction will ultimately hinder innovation. On the other hand, Company D is actively looking for safer alternatives. A company that replaced its DCM-based formulations with alternatives two years ago and now sells less than 10 tonnes of the new formulation has suggested that the cost of reformulation (to a DBE-based product) was no more than €2,000 at the time. The actual product cost is slightly higher compared to the old product (5-10%); however, sales have not been impacted. The experiences of this company are presented in Box 8.1 as a case study to provide a feeling of likely impacts from a restriction to a (small) formulator of paint strippers.

Box 8.1: Impact of Restrictions on Formulators

A formulator manufactured a DCM-based formulation in the past. It was aimed at a 'niche' market (furniture stripping) as part of a large product range and was sold in 500 ml tins only, unlike general-purpose paint strippers which are often sold in larger pack sizes.

The DCM-based product was replaced around two years ago by a DBE-based formulation which also contains a mixture of other solvents. The company has suggested that all the ingredients listed in the relevant Safety Data Sheet could be considered as 'active substances' as a variety of finishes will be found on old furniture, which can vary in 'resistance' to individual components. The DCM-based formulation was sold until late 2004. The DCM-free formulation entered the supply chain in late 2004 (effectively 2005). The change was accompanied by the following costs:

• total reformulation and marketing costs at the time of the switch (i.e. a one off cost):	€0.33 per kilogram of formulation sold (assuming that sales in 2004 were at the same level as in 2007)
• increase in actual formulation cost (cost to formulator):	5-10% (but closer to 5% than 10%)
• increase in trade price between 2004 and 2005 (cost to retailer):	5%
• increase in retail price between 2004 and 2005 (cost to consumer):	6.5% (estimate)

This case study shows that the cost of reformulation may be moderate and is passed on to traders and the consumer. Points of importance are:

- the reformulation cost will significantly depend on the original (DCM-based) composition and the new (DCM-free) composition. In this particular case, the specific aim of the company was to introduce a cost neutral change, if at all possible;
- a small part of the increased cost was absorbed by the formulator. However, this paint stripper represents a limited proportion of the turnover of the company (which overall exceeds €50 million) and the increased cost of the formulation did not create a significant problem;
- it appears that the retailers increased the retail price of the product above the level of the increase in the trade price;
- evaluation (laboratory tests) on a range of typical finishes suggests that the DCM-free product has broadly similar effectiveness to the DCM-based formulation although stripping speed is slightly slower;
- no adverse consumer reaction has been reported so, in practice, the formulator believes that the product has shown to be equally effective;
- product sales of the DCM-free equivalent have continued at expected levels;
- the company has no plans to market DCM-based products in the future; and
- the DCM-free product is classified as highly flammable owing to the presence of solvents as was the original DCM-based product which also contained solvents. As such, the company considers that it is no more, but no less, hazardous than the DCM-based product.

8.3.2 Benefits to Manufacturers of DCM-based Paint Strippers

Positive impacts (benefits) for the manufacturers of paint strippers could include:

- **sales of alternative paint stripping formulations**: from the responses received, it is evident that companies will generally switch to manufacturing alternatives if they wish to remain in business, unless their sales represent only a small part of their turnover (when they may consider whether they should invest in new products). In any case, a potential restriction will create opportunities for paint stripper manufacturers and several of them already have production lines for the alternative products;

- **potential reduction of costs for PPE in the production plant**: employees at manufacturing sites for DCM-based paint strippers are likely to need a variety of PPE (including gloves) depending on the nature of the task. These PPE could be expensive; for instance, fluororubber gloves cost around €50 per pair. A restriction on DCM-based paint strippers will reduce the manufactured tonnage for DCM and, therefore, the overall exposure of employees to DCM, which consequently may reduce the need for such gloves and possibly other PPE which might currently be in use;

- **possible avoidance of costs for controls on releases of DCM**: the status of DCM as a priority substance under the Water Framework Directive would mean that strict controls need to be in place to prevent releases to the aquatic environment. While these controls have not yet been determined by the Member States, it is possible that a reduced production tonnage would help in meeting the targets of the Directive;

- **advances in innovation and new products**: this could be a benefit in the long term (although it does require an investment at the beginning unless the company already has alternatives in its portfolio); and

- **opening of the market to many more companies that may be able to sell their alternative products (including SMEs)**: the removal of DCM-based paint strippers from the market will open up possibilities for business to a number of new players alongside those companies that switch from DCM to alternatives.

8.4 Impacts on Companies involved in Industrial Uses of DCM-based Paint Strippers

8.4.1 Costs to Companies involved in Industrial Uses of DCM-based Paint Strippers

No detailed quantitative information regarding costs has been received from direct consultation with users of DCM-based paint strippers. However, a number of sources of information have been brought together here to try and provide an indication of the potential (types of) costs which may be incurred by users involved in industrial uses.

Based on these sources, the potential additional costs to users from a restriction on the marketing and use of DCM-based paint strippers might include:

- an increased cost of the alternative formulation(s);
- the costs of changes in equipment and process modifications (e.g. any physical modifications to the tank used for dip stripping or to spraying/brushing equipment or changes in the stripping process);
- costs arising from increases in the duration of stripping operations; and
- administrative costs (e.g. training of personnel).

Obviously, such costs will not be applicable across all users. For instance, not all users carry out stripping in a tank; hence, there will be no costs from a physical modification to the tank or benefits from reduced costs of replenishing the tank.

Box 8.2 provides a summary of cost estimates found by previous assessments of the economic impacts of restrictions on the use of DCM-based paint strippers by different types of users. More recent data are presented below.

Box 8.2: Previous Assessments of Economic Impacts to Users involved in Different Industrial Uses of DCM-based Paint Strippers

An assessment of the possible costs to users from a restriction on the marketing and use of DCM-based paint strippers was presented in TNO (1999). The report considered three scenarios and presented the following costs (based on work undertaken by others):

- ***metal stripping***: sanding or treatment with blasting grit is the main alternative option. For an alternative based on NMP, a considerable capital investment and increased running costs would result in an annual cost increase of €700 per tonne of DCM (1999 prices); and

- ***furniture (wood) stripping***: for an alternative base don NMP and DBE costing an extra 60% and a 20% productivity loss due to extra-stripping time, the cost was estimated at about 20 to 25% of the original cost price for this activity, equivalent to about €800 per tonne DCM replaced (1999 prices); and

- ***airplane stripping***: TNO (1999) suggests that the price of benzyl alcohol-based alternatives rice incomparable. A clear advantage in moving away from DCM is a reduction of hazardous waste treatment costs, as DCM-containing residues have to be treated as chemical waste. The paint can be sprayed off with high-pressure water canons and flushed through to the water treatment plant. The working conditions may improve as a result of the use of the alternative.

According to the Danish Environmental Protection Agency (MST, 2002), work undertaken in Denmark suggested that the overall financial cost of totally replacing dichloromethane in paint/lacquer removers with combinations of both chemical and mechanical alternatives will be somewhere in the range of DKK 4-17m (€0.5m to €2.8m using the current exchange rate between DKK and Euro). A tax of €4-5/kg DCM (using the current exchange rate) was deemed capable of accelerating that substitution in the industry.

Cost of Alternative Formulations

As discussed in Section 5, the alternative formulations are generally more costly than DCM-based formulations. For instance, it has been indicated that the cost of DCM-based paint strippers for industrial use would be around €1.5/kg while alternatives may cost €3 to €8/kg (factor of 2-5). Table 5.15 also shows that the cost of DCM-based paint strippers could be around three times that of a specified alternative formulation (DBE, in this case).

The key factor which will influence the overall cost of the alternative formulation for an industrial user is the quantity required/used. There are significant difficulties in making assumptions regarding what paint stripping business may be considered as "average". For instance, a formulator of both DCM-based and DCM-free products has suggested that his company has customers who need to purchase DCM-based strippers every one to three years while others purchase about 750 litres every two months. The quantity that needs to be used in a tank (or indeed in any type of industrial paint stripping) is dependent on how big the user's tank is, how much work they put through it, if the have a lid to retard evaporation, how often it gets used (there may be significant fluctuations in workloads during the year). On the basis of the components that need to be stripped, a dip tank could be as small as 200 litres or as large as 5,000 litres. It has also been mentioned that the DCM tank (for instance in furniture stripping) is usually around two-thirds full (as a maximum), whereas the example alternative tank is enclosed and 100% full. Another consultee has noted that industries such as airplane paint strippers replace the strippers in their tanks more often then users in "usual" industries. Here, the composition of the paint is also important. Some removed paints may be dissolved in the stripper while other just float in small pieces on the surface of the stripper and thus can easily be skimmed. Obviously, a change of stripper fluid in the bath will be required more often than when skimming is sufficient for removing dissolved paints. A formulator has suggested that some of his customers face significant costs for waste disposal of DCM-based paint strippers so that tanks tend to get run until they are so slow at stripping that it slows throughput to an unacceptable level.

Using some rather simplistic calculations, it would appear that the average (additional) cost of using alternative formulations could be around **€3,000 to 10,000 per year per industrial user** (based on a user requiring 600 litres of DCM and 750 litres of an alternative formulation per month – with any number of replacements per year).

Cost of Modification of Equipment or Processes

A tank may need to be modified either for technical reasons or to comply with the restrictions. For instance, several consultees have noted that alternative systems based on high boiling point solvents or caustic soda need to be heated (usually at 80-90°C), while DCM stripping tanks are used at room temperature (20°C). This need to heat the tank could, therefore, mean that existing tanks have to be modified at a cost. It has been suggested that the cost of the tank for the alternative system could be up to four times the cost of a tank for a 'traditional' DCM-based stripping system; see for example, the case study presented in Box 8.3.

Box 8.3: Cost Incurred in Installing Ventilation System in Order to Meet Revised OEL

This case study demonstrates how methylene chloride exposures during furniture stripping can be reduced to below the US Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 25 ppm (as an 8-hour TWA). Five surveys were conducted at one facility; the first four resulted in employee exposure geometric means from 39 to 332 ppm. For the fifth survey local exhaust ventilation was used at the stripping tank and the rinsing area, which together exhausted 138 m^3/min (4,860 ft^3/min). Additional controls included providing adequate make-up air, adding paraffin wax to the stripping solution, raising the level of the stripping solution in the tank, and discussing good work practices with the employee. The employees' methylene chloride exposures during the fifth survey resulted in a geometric mean of 5.6 ppm with a 95% upper confidence limit of 8.3 ppm, which was found to be significantly lower than the OSHA PEL and the OSHA action level of 12.5 ppm. The cost of the ventilation system was $8,900.

Source: Estill *et al* (2002)

Similarly, a restriction which results in the installation of mechanical ventilation, for instance, would require some physical modification to existing equipment with costs. With regard to the potential cost of installing a closed system to prevent the exposure of the operator to DCM vapours, a cost of up to €100,000 has been suggested. This would be for a system that has been described as follows: "*the system is a very large and comfortable one; the main part is a sluice to bring the workpiece into the stripping machine without allowing the vapours of the cleaning agent into the working environment. The next part is the cleaning bath itself which provides mechanical movement as well as ultra sounds to improve the effectiveness of the cleaning process and to reduce the duration of cleaning. Another part of the system could be the possibility of drying the stripped workpiece within the machine. Finally, the system will come with distillation capabilities so as to allow the cleaning of the stripping formulation to reduce the need for replenishment and produce less waste*". A cost of €100,000 per installation is a significant capital investment and would be disproportionate and prohibitive for many SMEs who are active in the stripping industry.

There are also practical issues surrounding the use of closed systems. For example, consultees have indicated that it would be extremely difficult to introduce a closed system when very large workpieces need to be stripped (car bodies, airplane parts, etc.). A consultee with experience in the furniture stripping business, suggested that the idea of a closed system is not compatible (or practical) with the operations undertaken in the industry for a number of reasons (a) disposal of waste residue will be carried out manually, unless a sophisticated filtering system is installed; (b) items of furniture etc. need to be turned over, brushed, scraped etc; and (c) washing off dipped items after stripping will result in excessive fumes, so this part of the process would also have to be enclosed (with the associated cost and inconvenience). A requirement for the use of closed systems by all users involved in industrial uses would therefore result in disproportionate costs, given that engineering controls and PPE can be used to control exposure (although good working practices are also very important).

Increased Duration of Stripping Operations

Alternative formulations tend to act more slowly than DCM (although this may not always be the case). As a result, stripping operations may take a longer period of time if restrictions are placed on the use of DCM-based paint strippers. It is of note though that some industries or parts thereof have switched to alternatives that may work more slowly with no significant adverse effects. For example, in the aerospace industry, the majority of users nowadays use alternatives, mostly benzyl alcohol-based systems that work more slowly than DCM-based systems. This has not created any major problems despite the magnitude of the task of stripping an airplane and the potential economic and competitiveness issues that would arise from increased downtime.

Training

Employees will need to be trained in using alternative systems. However, such costs are likely to make a relatively small contribution to any overall changes in costs. In any event, employees should already be trained in the handling of dangerous preparations with the use of DCM-based paint strippers.

8.4.2 Benefits to Companies involved in Industrial Uses of DCM-Based Paint Strippers

The potential benefits to users of DCM-based paint strippers might include:

- reductions in the costs of waste treatment;
- reduction in the costs of replenishing strip tanks;
- reduction in the costs of extraction and ventilation;
- reductions in the costs associated with personal protection equipment requirements;
- reductions in the costs of complying with environmental legislation (e.g. those arising from the Water Framework Directive in relation to priority substances);
- reductions in insurance costs.

The potential importance of these different costs is discussed below.

Reduction of Costs for Waste Treatment

The cost of waste treatment can be a very important component of the overall cost of running a business that uses DCM-based paint strippers. A past owner of a UK furniture stripping company provided documentation on the cost of waste disposal in 1992. At the time, the total cost of disposing a 205-litre drum of waste each week was £175 per drum. According to the owner of the company, at the time, the cost of waste disposal represented just over 25% of the total running costs (including chemicals, waste disposal, labour, electricity, insurance). Soon after that, the company switched to a DCM-free alternative; one of the results of this change was a reduction in waste disposal costs of more than 75%.

The benefits from reduced costs of waste treatment may, however, not apply across all alternatives. For instance, DCM-based waste requires incineration. This tends to be expensive as DCM is not flammable and, therefore, needs burning at a very high temperature to achieve complete combustion. If there is sufficient DCM left in the waste, the user could send it for reclamation of the DCM part and then just pay for the disposal of paint sludge.

Non-DCM solvent-based products, if chlorinated, would result in similar problems regarding waste disposal. If non-chlorinated solvents are used (for instance, NMP), then the user may decide to choose reclamation or incineration (although another formulator has argued that alternative solvents generally cannot be recycled and re-used). It has been said to be unlikely to be cost effective/sufficiently efficient to compress the paint skins, remove the solvent and then landfill the solid waste. Caustic-based strippers are water based (run hot), so the user could remove solids and neutralise the alkalinity and then potentially dispose of the remaining wastes to drain, provided there are no dangerous or harmful materials left in the solution (this is clearly not an option for stripping aluminium components).

Reduction of Costs for Replenishment of the Dipping Tanks

The volatility of DCM means that the solution in a strip tank may need to be replenished at regular intervals. This will inevitably have an additional cost which may not apply when a less volatile alternative is used. However, one formulator has argued that some (unidentified) alternative paint strippers cannot be made effective again with a small refill into the tank; instead, the bath has to be changed completely.

Reduction of Costs for Ventilation and PPE

The magnitude of any reduction in costs in ventilation requirements will depend on the type of alternative to be used, the temperature of the application and the type of application (brush, tank, etc.). No further data are available to enable an estimate of possible savings to be developed.

With regard to PPE, this can be a very important component of the costs of running a business that uses DCM-based paint strippers, however, it is often a hidden cost. Consultation suggests that companies may disregard the requirements of the existing legislation with regard to taking measures to protect their employees. A quick calculation could show how important the savings from the elimination of need for sophisticated PPE could be: if a company strips articles over 220 days a year and has three employees working for around 8 hours a day, each one of them would have to use 3 pairs of fluororubber gloves (as in most cases exposure to water - due to spraying, rinsing, etc. - would render the use of PVA gloves unsuitable). The cost of using three glovers per day would be 3 x 3 x €50 = €450 per day. Over a whole year, the cost of gloves could be as high as 220 x €450 = €99,000. Furthermore, if the user needs to undertake spraying in a booth or cleaning open vessels, air-fed respirators would be needed with an additional cost. These costs could be significantly reduced with some of the alternatives.

Reduction of Costs of Controls for Complying with Existing Legislation for the Environment

It is not currently possible to quantify the reduction in costs which may result from process no longer being subject to legislation such as the proposed Environmental Quality Standards Directive which implements Article 16 of the Water Framework Directive. The status of DCM as a priority substance under the Water Framework Directive would mean that strict controls need to be in place to prevent releases to the aquatic environment. While these controls have not yet been determined by the Member States, it is possible that measures could be required of users.

Reduction in Insurance Costs

The past owner of the furniture stripping business referred to above has suggested that the switch to the alternative meant that his insurance costs reduced by more than a half.

8.5 Impacts to Companies involved in Professional Uses of DCM-based on Paint Strippers

8.5.1 Costs to Companies involved in Professional Uses of DCM-based on Paint Strippers

In order to assess the costs and benefits to companies involved in professional uses in the event of a restriction on DCM-based paint strippers, a case study has been developed largely based on a typical job undertaken by a company involved in professional uses. The company removed paint from the front of a residential property. The job was described as follows:

- the paint had two coatings, the first coating was oil-based paint and the topcoat was a masonry paint;
- the paint stripper was applied by brush to soften the coatings and a 120°C steam cleaner was used to remove the paint;
- 100 litres of DCM-based paint stripper were used;
- it took an average of 3 applications of this product to restore the brickwork; and
- the project took 6 days with 2 employees involved.

Cost of Paint Stripper

Depending on the alternative formulation used, it is assumed that the user may need 0.5 to 1.5 times the quantity of DCM-based paint stripper used (in this case, 100 litres). The information available suggests a cost of DCM-based paint stripper to the user of €1.5/kg (€1/litre) and a cost of solvent-based DCM-free paint stripper as €3 to €8/kg. These figures are equivalent to ca. €2/litre to €6/litre. For an alkali-based paint stripper the price per litre could be half of that of DCM-based paint strippers. The alkali-based paint strippers may have the lowest coverage among alternatives. Therefore, while the cost of 100 litres of DCM-based paint stripper would be €100, the cost of an alternative could range from **€75** (€0.5/litre x 150 litres) for an alkali-based product to **€600** (€6/litre x 100 litres) for an expensive solvent-based product.

Cost of Respiratory Equipment and Forced Ventilation

The type of respiratory equipment that should be used by the employees will depend on the risks determined by the employer. If it is assumed that respiratory protection is required, then an independent respirator will be needed when using DCM-based paint strippers. An industry representative (paint decorators) has suggested that a self-contained breathing mask (with air supply) would cost at least €200, although systems with a cost of €1,200 or more are also available on the market. On the other hand, when alternative paint strippers are used, an organic vapour respirator (with A1 filter type) could perhaps cost €100. For two employees, the cost would be **€400 - 2,400** for DCM-based products and **€200** for DCM-free paint strippers.

The cost of additional forced mechanical ventilation (mechanical fans) working on electricity has been estimated at **£60 per week**.

Cost of Gloves

It is assumed that each operator will use two pairs of gloves each day. The two operators handling DCM-based paint stripper would use one pair of fluororubber gloves each. On the other hand, the two operators not using DCM-based products would require a total of two pairs of, say, butyl rubber gloves (we chose this type as they are among the most expensive ones (see the Carl Roth Internet site available on www.carl-roth.de)). Hence, the cost for the operators using the DCM-based paint stripper would be **€100** (2 x €50). For those using the alternative paint strippers, the cost will be **€34** (2 x €17).

Costs from Increased Duration of Paint Stripping Operation

For the purposes of this case study, it is assumed that the alternative paint strippers would take a longer time before the paint is removed compared with DCM-based paint strippers. This delay could be dealt with more easily if the user is involved in a lengthy project in which, for example, the paint stripper may be applied on one surface and then while the stripper starts acting, the user moves on to the next surface (say, the next wall) for another application of the paint stripper. Technical datasheets for non-DCM paint strippers suggest a longer time required for the paint stripper to act. This additional time could be as long as 24 to 48 hours. Therefore, it is assumed that a project that would take 2 or 3 days when using DCM-based paint strippers would be prolonged by an extra day. It is considered unlikely that longer stripping times would cause operators to remain completely idle for more than one day. Assuming professional fees of €20/hour, the cost from the increased duration for paint stripping will be **€150** (7.5-hr day). The prolonged stripping operation would also probably means that the company would incur the cost of an extra day's worth of gloves i.e. a further **€34**.

It should, however be borne in mind that alternative formulations may also require a smaller number of applications. For example, some caustic products are marketed as being capable of removing more than 30 coats of paint in one application. Also, it is the case that the manner in which DCM-based products are currently used allows users to save time which, under circumstances of full compliance with existing legislation, would not be the case. For instance, time losses from not undertaking a proper risk assessment or using the appropriate PPE (e.g. respiratory equipment) which can make the undertaking of stripping operations awkward and impractical are not accounted for.

On the other hand, delays have a more severe impact when the work to be undertaken is minor, for example, removal of graffiti from a wall. A company that specialises in graffiti removal may need to attend several locations to remove graffiti. For these short tasks, an alternative that requires a significantly increased time could cause a serious disruption in business. However, not all alternatives require a very long period of time to act and the variety of products currently on the market could possibly allow the user to choose a product, the application of which would cause the smallest possible disruption.

Finally, the use of any alternative that requires a delay of 24 hours or more would probably require that measures be taken so that the presence of the stripper on the substrate does not pose a hazard to passer-bys, customer, children, pets, etc. The cost of these measures is currently unknown.

Cost of Waste Disposal

At the end of each job, the operators need to dispose of any waste in the appropriate manner in accordance with hazardous waste legislation. The presence of DCM requires that any waste be disposed of properly; however, this does not automatically mean that such disposal requirements would not apply with any of the alternative paint strippers. In fact, the nature of the removed paint could make the waste hazardous and would require appropriate waste disposal action irrespective of the paint stripper used. As a result it is not possible to quantify the difference in costs, however, it is likely that this will be lower when DCM-free paint strippers are used.

Overall, the cost for stripping under the two scenarios of the case study are given in Table 8.4. A key observation is that the costs of using DCM-based paint strippers may be significantly higher than using an alternative. The calculations, however, are based on the use of appropriate PPE.

Table 8.4: Estimates of Cost Difference for Paint Stripping Operations by Companies involved in Professional Uses with and without DCM-based Paint Strippers

Cost component	Paint stripping with DCM-based paint strippers	Paint stripping with DCM-free paint strippers
Cost of paint stripper	€100	€75 to €600
Cost of respiratory protection	€400 to €2,400	€200
Cost of gloves	€100	€68 (based on two days)
Cost on increased duration of paint stripping	0	€100
Cost of waste disposal	'Baseline'	'Baseline'
Total	***€600 to €2,600***	***ca. €450 to €1,000***

Consultation shows that the recommended use of PPE is not always followed. Expenditure on PPE by professional users appears to be much more modest (based on the information provided by users discussed in Section 4).

Table 8.5: Glove Protection for Professional Uses of DCM-based Paint Strippers	
User and key parameters	**Gloves usually employed**
Professional user A • Involved in building maintenance • Stripping paint from various materials, principally timber, stone and plaster. ***Typical annual use***: >500 litres annually ***Employees***: 1,000 (only a small proportion involved in paint stripping)	***Individual costs:*** Nitrile gloves - £2.00 per pair Forced ventilation cost - £60 per week (if needed)
Professional user B • Paint removal from building facades ***Method***: brush ***Typical annual use***: 2,500 – 3,000 litres ***Employees***: 6	***Individual costs:*** Suits - £60 each Gloves - £5 per pair Visor/Mask - £50 each Wellington boots - £30 per pair ***Replacement rates:*** Mask refills: 2 per every 5 days Visor/mask: 2 per every 5 days ***Total annual cost:*** £1,700 (around €2,400)
Professional user E • Exterior/interior brickwork, plasterwork, render and delicate metalwork ***Method***: brush or airless spray ***Typical annual use***: 750 litres ***Employees***: 4	***Individual costs:*** Replacement visors - £4.50 per pair Coveralls - £20.00 each Gloves - £2.20 per pair ***Total annual cost:*** £4,200 (around €6,000)
Source: Consultation	

The information provided by Professional User B on total annual expenditure on PPE is considerably lower than the cost of the single job described in the case study, despite the fact that this company uses up to 3,000 litres a year (30 times the amount used in the case study) and employs 6 operatives. This is due in part to the fact that different types of PPE are obviously used and the rate at which PPE is replaced is much different to that assumed in the case study. It thus appears that users are either unaware of the risks or possibly that adapt their approach to health & safety issues for cost and/or time/effort reasons.

Also, the above estimates do not account for any reduction in the employee liability insurance that the companies involved in professional uses might achieve when switching to alternatives.

8.5.2 Benefits to Companies involved in Professional Uses of DCM-based Paint Strippers

Potential benefits to companies involved in professional uses of DCM-based paint strippers could include:

- a reduction in costs for waste disposal;
- a potential reduction in costs for ventilation;
- a reduction in costs for PPE;
- a reduction in insurance costs; and
- a reduction in waste disposal costs.

Overall, the switch to alternatives may result in economic benefits for users, although this will depend on how severe the delays would be in completing the paint stripping work. Notably one such user has suggested that the result of a restriction on the marketing and use of DCM-based paint strippers would be an increase in the company's rates by 30%. This estimate is influenced by the current perception of the users of what constitutes adequate protection, which creates the false impression that DCM-based paint strippers are rather inexpensive to use.

8.6 Impact of Restriction on Consumer Uses of DCM-based Paint Strippers

8.6.1 Costs to Consumers of DCM-based Paint Strippers

There are three main costs that may be incurred for consumers:

- *direct costs*: where these relate to the potentially (extra) cost of the alternative formulations used in place of DCM-based paint strippers;

- *indirect costs*: where these relate to the cost of the equipment (including PPE) that is (determined by) and required for use with any paint stripper; and

- *other opportunity costs*: where these relate to the costs incurred from additional time and inconvenience required for the use of some of the alternative paint strippers.

In order to assess the likely costs to the consumer in the event of marketing and use restrictions on consumer use of DCM-based paint strippers, a case study has been developed. If DCM-based paint strippers are not available to the consumer, it is likely and expected that the consumer will visit the local retailer to enquire about another method of stripping; this could, most likely, be an alternative chemical-based paint stripper or some mechanical (sandpaper etc.) or pyrolytic (blowtorch, etc.) form of stripping. For the purposes of this case study, it is assumed that the consumer's first choice will be an alternative chemical-based formulation.

Cost of Alternative Formulation

For costing purposes, it is assumed that the consumer is undertaking DIY renovation work in his/her home and has to strip three doors (both sides). When a DCM-based paint stripper is used, the quantity required will be around 4.5 litres (3 x 1.5 litres) of product (one manufacturer notes on its package "*One litre covers from 2 to 3 square metres (enough for 1 to 2 standard door sides)*"). If an alternative formulation is used, then the consumer might need between 2.25 litres (4.5 x 0.5) and 6.75 litres (4.5 x 1.5) (depending largely on the specific product used and the thickness and age of the paint that needs to be removed).

The information presented in Section 5.13.5 shows that the current per unit cost of alternative formulations could be 2 to 3 times higher than that for DCM-based formulations. The cost of purchasing the paint stripper, therefore, could be around €45 (€10 x 4.5) for the DCM-based product and from around €45 (€20 x 2.25) up to ca. €122 (€27 x 4.5) for the alternative formulation, depending on the alternative formulation and its coverage characteristics and price. The highest required volume calculated above (6.75 litres) has not been used for the calculation as this volume would probably realistically be needed for an alkali-based product which does not have the highest retail price (in fact, it may be less costly than DCM-based paint strippers).

Cost of PPE

When DCM-based paint stripper is used, the most appropriate gear would include fluororubber gloves and goggles. With alternatives, less sturdy gloves would be required (possibly PVC or polychlorprene or nitrile ones). The fluororubber gloves cost €50-€90 per pair[53] while the ones suitable for the alternative formulations possibly cost €2 to €5 per pair (most likely closer to the lower end of this range). Although these two types of gloves have different breakthrough times, it is assumed for simplicity that the consumer uses one pair of glove throughout the stripping of the three doors irrespective of the type of gloves. The need for and cost of other types of PPE required (for instance, goggles) is not taken into account as they are assumed to be either similar in both cases or dependent on the conditions of use of the paint stripper. For instance, a consumer may need a respirator with an independent air supply when stripping furniture in a basement without windows but may not need one when stripping a door in a room with the windows open.

Cost of increased duration of paint stripping

There have been a number of claims as to the additional time needed for a job to be completed when alternatives are used. Some products (caustic pastes, for instance) require that the product is left on the substrate for several hours, ideally overnight (say, 12 hours). For the case study, it is assumed that these 12 hours do not represent time lost for the simple reason that the consumer is unlikely to stay up overnight watching over the paint stripper. A more likely scenario is that the consumer will reorganise his/her work, while waiting for the stripper to act. It is assumed, therefore, that where alternatives take longer, the actual time lost is between 1 to 2 hours (taking into account the fact that there is a general trend for wider use of water-based coating on which alternative paint

53 A price of €50 has been quoted in a number of sources (for instance SCHER, 2005), however, an online search on suppliers' Internet sites shows prices around €90. Note that consumers will be buying individual pairs of gloves and the price for them would be considerably higher than for a company buying in bulk.

strippers may perform better than DCM-based ones). Using this range, it is possible to calculate the value of time lost based on estimates on the 'value of non-working time' derived by the UK Department for Transport[54]. In 2002 figures, the value was £4.46 or (using the ten exchange rate) about €6.62 per hour. Inflating to current prices, the additional cost to the consumer from the relative delay in completing the stripping job may be ca. €7 to €13.

The above figures are summarised in Table 8.6. As can be seen from the table, the current cost to consumers from using alternative formulations (€54 - €140) compares favourably with the current costs of using DCM-based paint strippers (€95 - €137). This does not take into account the fact that in the event of restrictions, the prices of the alternative formulations are likely to fall as production increases and consumer demand increases.

Table 8.6: Costs to Consumers from using DCM-based and DCM-free Paint Strippers

Cost component	**DCM-based paint stripper**	**DCM-free paint stripper**
Cost of formulation	€45	€45 – 122
Cost of PPE	€50-90	€2-5
Cost of (additional) lost time	€0	€7-13
Overall cost	**€95-137**	**€54 - 140**

8.6.2 Benefits to Consumers of DCM-based Paint Strippers

Overall, two main benefits which will accrue to the consumer, those relating to:

- the lower overall costs of paint stripping (and hence savings to the consumer); and
- the reduced health risks that the consumer may be exposed to when using alternatives (although, not necessarily all of them) as compared to DCM-based paint strippers. It has not been possible to quantify these meaningfully in monetary terms.

Also, when DCM-based paint strippers are used, the waste is invariably not disposed of in an appropriate manner. Substitution (as a result of restrictions) will result in a reduction in such wastes with benefits to the environment.

8.7 Impacts and Costs on Other Stakeholders

8.7.1 Economic Impacts on Retailers

Limited information has been received from retailers of paint strippers; only two major DIY retail chains in the UK (which may cover about 50% of DIY paint stripper sales)

54 See the Transport Analysis Guidance Website www.webtag.org.uk/webdocuments/3_Expert/5_Economy_Objective/3.5.6.htm.

have provided information. It appears that DCM-based paint strippers currently represent the vast majority (potentially up to 80%) of paint strippers sold by these DIY stores. One of the companies has suggested that replacing DCM-based strippers would be likely to result in lost sales revenue as not all chemical alternatives can achieve the same result, hence consumers may look to overcome their paint stripping tasks by other means not necessarily available through a retail outlet. Alternatives also carry a higher unit purchase cost both to the retailer and the end user.

In assessing the potential impacts of restrictions, it is considered that since retailers stock both DCM-based and DCM-free products, the consumer is likely to visit such stores in the first instance and will probably purchase an alternative paint stripper. Assuming that the alternative is effective, the consumer will purchase it again the next time he/she wishes to undertake DIY paint stripping. Where it is ineffective, the consumer is likely to return to the store to ask questions or seek an alternative product. As concluded in Section 5, users would need to undertake a more detailed assessment of the task at hand and of what the necessary stripping materials should be (unlike the situation with DCM, which allows for several types of coatings to be removed without the user knowing exactly what type of coating he is dealing with). This would require more focus and knowledge from the user and, by consequence, the retailer.

Overall, impacts on retailers are expected to be even across Europe as long as the restriction applies uniformly; any market losses are likely to be due to a particular retailer not stocking the alternatives relevant to the consumer. It is of note that while DIY chain stores are present in many countries around Europe, there may still be a strong independent sector supplying paint strippers to the public in some Member States.

It is interesting to note the changes in price of the alternative product that a formulator introduced to the DIY in recent years and is described in Box 8.1. The cost increase to the retailer was 5% while the retail price increased by an estimated 6.5%. Therefore, the retailer did not make a loss from the change.

8.7.2 Economic Impacts on Pharmaceuticals Companies

DCM is used (mainly) as a solvent in the pharmaceuticals industry. Spent DCM may be passed on to recycling companies, recycled and then sold to manufacturers of paint strippers in Europe.

In the event of restrictions, the pharmaceuticals companies may consider the following solutions for treating their spent DCM:

- re-using it in their process, wherever feasible;
- recycling it (part of which currently ends up in paint strippers); and/or
- diverting it to high-temperature incineration.

Recycling of spent DCM has a variable importance for different pharmaceuticals companies:

- one company noted that they have to pay for the removal of DCM from all locations where the solvent is used;

- a second company advised that the solvent market is fickle and prices/costs frequently change. However, traditionally, DCM recycling companies have been willing to take the spent DCM for no charge (recently they have begun to pay the pharmaceuticals company for the spent DCM). No charge is made for transport;

- a third company indicated that they are paid a fee by the recyclers for the DCM, based upon the purity of the solvent. Solvent that has very low purity or high water content cannot be used by the recyclers and the company must pay to have this disposed of. Note that this company is located in the US; and

- a recycling company suggested that they are usually paid for recovering the spent DCM, but sometimes they "purchase spent DCM for nothing".

It is evident that the purity of DCM will define to an extent the fate of the spent material, which will in turn depend on the specific production processes used by the pharmaceuticals companies. For instance, one company has noted that, in 2005, its recycling rate for DCM was around 10%; in previous years, when DCM was used in other processes, the company had a recycling rate of up to 30-35%. Another company notes that the increase in DCM sent to outside recyclers is driven entirely by production volumes. The company's main product, a cancer treatment, has seen significant growth in sales since its introduction to the market in the last decade. DCM is used in all three manufacturing steps and, therefore, any increase in sales of the final product has a multiple effect on the volume of DCM used at the site.

On balance, for the purposes of this analysis, it can be assumed that the pharmaceuticals industry as a whole does not earn or lose money to the recycling industry when spent DCM is passed on to recyclers.

Impacts from a Potential Restriction

If total or partial restrictions on DCM-based paint strippers were introduced, there would be a reduction in demand by the European paint strippers industry. This outlet for spent DCM coming from pharmaceuticals industry would therefore diminish. The result of this could be one (or a combination) of the following:

- the pharmaceuticals companies would continue to pass their spent DCM onto recycling companies: there could be a surplus of spent DCM if other outlets for it could not be found. This could lead to a fall in prices, benefiting the pharmaceuticals industry; or

- the pharmaceuticals companies would divert their spent DCM to high temperature incineration; or

- the pharmaceuticals companies could implement waste minimisation programmes and internal recycling systems to minimise production of spent DCM that needs to be disposed of/recycled by a third party.

It is also possible that the pharmaceuticals companies could find difficulties in passing their spent DCM to recycling companies and may now be charged at all times for doing so. It has been suggested by a pharmaceuticals company that recycling companies may currently be seeking recycling routes outside of Europe. A US pharmaceuticals manufacturer suggested that the introduction of recycled material from Europe into the US could disrupt the US marketplace.

This highlights two issues:

- recycled DCM can be used in other applications besides paint strippers, as indicated by the manufacturers of DCM (this is one of their concerns on potential adverse impacts to their businesses from a restriction);

- while the use of recycled DCM in the manufacture of paint strippers has been referred to by several consultees, the true extent of this practice is unclear. On the basis of the information received, five companies specifically indicated that they do not use recycled DCM while four indicated that they do. The remaining respondents did not provide an answer or did not know. Out of the four users of DCM (one of which notes that only 25% of their consumption is recycled DCM), two have suggested that the quality of the recycled product may not be acceptable or, in fact, consistent. Hence, as explained in Section 2.2.2, some companies are generally reluctant to use recycled DCM. A third company, which uses a considerable amount of recycled DCM, owns a recycling facility and simply uses its own reclaimed material. Therefore, the importance of recycled DCM (re-)entering the paint stripper formulation market might be overestimated.

With regard to the second scenario, pharmaceuticals companies would have to pay for their spent DCM to be incinerated at high temperature[55]. The range of estimates received from a pharmaceuticals company and a recycling company on the likely cost is €900 to €2,000 per tonne of DCM (where the cost depends on the tonnage to be disposed of). Using these figures with the estimated tonnage of recycled DCM used in paint strippers of 1,500-11,000 tonnes (see Section 2.2.2) indicates that the cost for high temperature incineration would be between **€1.4 million to €22 million**. This does not include any possible changes in price (perhaps due to incinerator capacity issues) or the impact on the environment from the incineration of an additional quantity of a chlorinated solvent (which cannot be predicted or quantified).

Under the third scenario, the pharmaceuticals companies would have to find ways of minimising their production of waste DCM or ways of re-using it. Section 2.2.2

[55] An EU pharmaceuticals company also noted that EU incinerators would indeed have sufficient capacity to deal with the influx of spent DCM, however, certain low price non-chlorinated solvents might be diverted to cement/lime kilns to "free up" capacity for DCM. On the other hand, a US manufacturer argued that EU incinerators would not be able to cope and spent material could be sent abroad (to the US) for disposal.

discussed efforts made by companies to minimise their waste. However, as indicated, it is often not possible for quality reasons to use recycled/redistilled solvents instead of 'virgin' solvents in the pharmaceutical industry. Even where the re-use of DCM within a manufacturing processes is possible, the company might need to satisfy various regulatory bodies that this would not affect the efficacy/stability of products; this has been suggested as being extremely time consuming (likely to take several years) and costly. Therefore, it may be assumed that this type of response is the least likely, at least in the short term, leaving pharmaceuticals with a need to dispose of their spent DCM.

8.7.3 Economic Impacts on Solvent Recycling Companies

A restriction on the marketing and use of DCM-based paint strippers may have an impact on the recycling companies. Information has been received from two of them:

- the first is a small company, does not sell any of its reclaimed DCM to paint stripper manufacturers. The company earns between €100 and €400 for each tonne of DCM it recycles (this is the difference between what the company charges upon collection of the material and the cost of processing the waste and reclaiming the solvent); and

- the second company has suggested that a reduction in the number of possible applications for recycled DCM would force prices to move downwards and this could possibly mean a loss of about 20% of their DCM-related revenue. It should be noted that the company sells the reclaimed DCM to distributors and, hence, has no information on whether the reclaimed material is used in paint strippers or not. The estimate of 20% losses is hence based on an educated guess.

Overall, it cannot be predicted at present what the likely impact of a restriction will be on recyclers, however, it is always possible that recyclers may distribute their products in countries outside the EU.

8.8 Summary of Costs and Benefits to Industry

8.8.1 Conclusion on Potential Impacts of Restrictions on Manufacturers

Manufacturers of DCM are likely to incur two main costs:

- ***lost profits from lost sales***: the decrease in revenues from the loss of sales is estimated at around €13 million per year, with this translating to actual losses in profits ranging from between €1.3 million to €3.2 million per year. Taking a 33% split between industrial, professional and consumer uses, the lost profits per use category would be between **€430,000 and €1.1 million per year per use category**; and

- ***losses relating to a potential price drop***: estimated at around €9.8 million per year for the European market or €23 million for the global market, depending on which markets will be affected. Again, taking a 33% split between industrial, professional and consumer uses, the lost revenue (assumed here to reflect decreases in profit margins) per use category will be from around **€3.3 million** up to **€7.7 million per year per use category for European or global sales respectively**.

It should also be noted that more generally, sales of DCM for paint stripping manufacture account for only a small part of the total DCM sales for the manufacturers. This is shown in Table 8.6. Moreover, sales of 'virgin' DCM (and particularly sales to paint stripper manufacturers) have been steadily diminishing over the last 10 years (see also Table 2.5).

Table 8.6: Importance of DCM Sales to the Paint Stripping for the Six DCM Manufacturers

	Companies					
	A	B	C	D	E	F
European paint stripper-related sales as a percentage of global sales of DCM	5%	5%	1%	10%	4%	4%

Source: Consultation

It should, however, be borne in mind that the six manufacturers of DCM are very likely to compensate part of their losses from increased sales of ingredients of alternative paint strippers (such as DMSO and sodium hydroxide). The extent of these benefits cannot, however, be accurately predicted or quantified at present.

For manufacturers of DCM-based paint strippers, the economic impacts of a restriction are unlikely to be as high as those described by the UK Formulators Group, since alternative formulations are already available and several of the manufacturers of DCM-based paint strippers already offer them. While there might be an increase in raw material costs and a need for some alterations to their production facilities, the likely benefits from a restriction should offset to some extent the likely costs.

8.8.2 Conclusions on Impacts of Restrictions on Users

Companies involved in Industrial Uses of DCM-based Paint Strippers

A restriction on the marketing and use of DCM-based paint strippers is likely to have an impact on many users involved in industrial uses, particularly with regard to: (a) the increased cost of alternative chemical preparations and (b) the capital costs of adapting existing installations for use with the alternatives. These costs could indeed be significant especially for SMEs working with low profit margins. Other potential costs include the costs of an increase in the duration of the operations and the need to heat the dip tanks with some alternatives (wherever a tank dip system is operated).

All of these costs will be (at least) partly offset by the benefits expected for users in terms of reduced costs of waste treatment (although not in every case), reduced costs for ventilation, reduced costs of PPE and reduced insurance premiums. In the example of the furniture stripping business, the owner has indicated that after an initial capital investment of £3,000 (1992 prices) for new equipment and an initial cost for filling the strip tank, the operating costs of the company reduced by around 35%.

The impact of restrictions may be somewhat different for companies involved in aircraft paint stripping, where the main difficulties may arise from specifications requiring the use of DCM-based strippers for military aircraft. An assessment of the potential impact of a restriction by companies that supply DCM-based and DCM-free paint strippers to the aircraft stripping sector more generally though suggests that a restriction would have limited economic and employment effects. While stripping times are increased when using modern products and workflow improvement may be necessary to avoid idle times, there has been a drive in the last 10-15 years away from DCM with sustainability becoming part of the philosophy of big commercial companies (airlines), and chlorinated hydrocarbons being added to companies' black lists.

Companies involved in Professional Uses of DCM-based Paint Strippers

The generic case study clearly suggests that, following a restriction on the marketing and use of DCM-based paint strippers, the use of alternatives may be accompanied by net savings. This may not be obvious to tradesmen at present since they are accustomed to using DCM-based products without a proper assessment of the risks and, it would appear, without the PPE that is appropriate to the chemical and its hazards. The savings arising from switching to alternatives could prove to be very significant, particularly in paint stripping operations where engineering controls are inadequate and self-contained breathing masks with air supply should be used.

There may be issues arising from the slower action of alternatives which means that operations may take additional time to complete and that the user needs to change his habits and patterns of work (so as to minimise losses from idle time). Companies with larger operations may be more able to accommodate such changes and absorb any ensuing costs than smaller businesses. It is more likely that smaller businesses rely on the quick completion of small tasks, and their ability to do so may be considerably affected if the alternatives that work well are slow acting formulations.

Consumer Uses of DCM-based Paint Strippers

Following from the assessment of costs and benefits, it is considered that from a purely financial point of view, restrictions on the marketing and use of DCM-based paint strippers are unlikely to be financially damaging to the consumer.

The price advantage from using DCM-based paint strippers relates only to the relative costs of stripping formulations. If a requirement were placed on consumers to use DCM-based paint strippers only when the appropriate PPE is used (i.e. fluororubber gloves and an independent respirator, as necessary) (*Measure C4* in Section 7), the cost of stripping with DCM-based paint strippers would increase significantly, as would the inconvenience to the user. Consumers may well respond by moving to alternative stripping methods. Since national authorities would not be able to enforce such a restriction (as discussed in Section 7), a straightforward prohibition of consumer uses of DCM-based paint strippers would be more effective as a risk reduction measure.

8.8.1 Conclusions on Impacts of Restrictions on Other Stakeholders/Third Parties

In terms of costs, some impacts (particularly, relating to inconvenience) may be expected on distributors. However, little information or indication of such impacts has been provided and it may be assumed that they are unlikely to be significant. For instance, a Czech company distributing approximately 50 tonnes of two paint stripper types indicates that the overall receipts from this outsourced production amount to 3 million CZK (just over €100,000); but this is rather insignificant in relation to the total turnover of this company (AVNH, 2006).

Manufacturers and suppliers of (other) components of DCM-based formulations (e.g. methanol) may also be affected by any restrictions. Since the total weight of this large variety of components tends to make up only 10-40% of the DCM formulation and these substances may also be used as components of alternative paint stripping formulations, the impacts are unlikely to be damaging in the medium to long term.

In general, a restriction on DCM-based paint strippers would potentially open up a market of several thousand tonnes of solvents per year that would need to be used in alternative formulations. This would create new business for those companies producing these solvents (and DCM manufacturers and manufactures of DCM-based paint strippers could well be among them).

A number of manufacturers of alternatives have commented on the likely impacts to their business from a potential ban on DCM-based paint strippers. They have been consistent in suggesting that any such restriction would result in business growth and the need for hiring additional personnel. Unfortunately, there is insufficient information on which to provide meaningful quantitative estimates of the likely benefits to these stakeholders from a restriction on the marketing and use of DCM-based paint strippers.

An indication of the likely size of the markets for manufacturers of alternative 'active' ingredients of chemical paint strippers may be estimated. We assume that out of the total of 40,000 tonnes of DCM-based paint[56], some 10,000 tonnes (25%) will be replaced by mechanical stripping (with the associated benefits for the companies that supply relevant equipment) and the remaining 75% will be replaced by alternative chemical paint strippers. If a 1:1 tonnage replacement is assumed (i.e. the remaining 30,000 tonnes of DCM-based formulations will be replaced by 30,000 tonnes of alternative formulations) and the cost of alternative formulations range from €3-8/kg, then the size of the new market for alternatives could potentially be valued at **€90 million to €240 million**.
Finally, the uncertainty surrounding the DCM-related fatalities and accidents data does not allow for a meaningful quantitative assessment of the potential benefits from a reduction in deaths, injuries, accidents and diseases from exposure to DCM-based paint

[56] This is the maximum estimate presented in Section 2.2.2 and includes the tonnage of recycled DCM (from the pharmaceuticals industry).

stripping. Such costing was, however, undertaken in the US a few years ago and the relevant information is reproduced in Box 8.4 below.

Box 8.4: Benefits from Avoidance of Mortality and Morbidity from DCM – US Estimates

The US OSHA conducted a quantitative risk assessment based on a physiologically-based pharmacokinetic (PBPK) model incorporating rodent and human metabolic information. That analysis showed a final estimate of risk of 3.62 deaths per 1,000 workers occupationally exposed to 25 ppm DCM for a working lifetime. An alternative analysis, which incorporated all of the data used in the main analysis plus the assumption that human enzymes are less reactive to DCM (as compared to mice), gave a risk estimate of 1.23 deaths per 1,000 (OSHA, 1997). At the prior 8-h TWA of 500 ppm, lifetime occupational exposure to DCM could result in approximately 125 excess cancer deaths per 1,000 exposed workers.

The 25 ppm standard (which was subsequently introduced in the US) was expected to prevent an estimated 31 cancer deaths per year and an estimated three deaths per year from acute central nervous system and carboxyhaemoglobinemic effects. It would also reduce cardiovascular disease and material impairment of the central nervous system. The estimated cost, on an annualised basis, was $101 million per year (OSHA, 1997). This is equivalent to around €114 million per annum in 2006 (taking into account the 1997 exchange rate from US dollar and Euro and the retail price index, but with no adjustments for differences in the populations exposed).

In understanding this figure, it should be borne in mind that:

- the old 8-h TWA in the US was considerably (five times) higher than the current highest European OEL. On the other hand, the new 8-h TWA of 25 ppm is much lower than the majority of OELs in European countries;
- the estimated benefits will accrue from all industries using DCM, rather than the use of DCM-based paint strippers only; and
- it is not known for certain that practices when using DCM-based paint strippers in the US are similar to those in Europe (although information in the open literature does not suggest any differences).

Source: OSHA, 1997

8.8.2 Impacts of Restrictions on Employment, Innovation, Trade and Competition

The majority of companies consulted did not anticipate any impacts on employment levels; however, for some this depends on whether a suitable alternative could be developed. While it is impossible to accurately predict the success of any company switching from DCM to alternatives, it may be expected that those companies with existing alternative products in their portfolio would have a relative competitive advantage. Overall, impacts on employment should be limited, especially since many companies are ready to offer alternatives to their customers.

Regarding innovation, there was a mixed reaction from companies on whether any potential restriction may spur or hinder innovation.

From a competitiveness point of view, it cannot be predicted what the impacts would be for individual companies as this would depend on their supply chain, the scope of any restriction and how well each company is prepared for the situation after a restriction. It is true, however, that a restriction on the marketing and use of DCM-based paint strippers could theoretically lead to an increase in mechanical stripping, impacting on the overall size of the European chemical stripping market.

It is important to note that the paint stripping sector as a whole is characterised by stable demand, as it is an essential process for the metal treatment, construction, home decoration (DIY) and building restoration and maintenance markets. Any restrictions (or price increases) imposed on a particular paint-stripping product are thus unlikely to have a significant impact on demand – rather it will result in an increase or redistribution of costs amongst relevant manufacturers and users. In this regard, it should be borne in mind that several manufacturers of DCM-based paint strippers in the EU also manufacture DCM-free alternatives and may already have a well-established position in the alternatives market. This would allow them to compensate some of their losses from a restriction on DCM-based formulations with sales of alternatives (which naturally would increase once DCM-based products are removed from the relevant markets). Also note that there are currently manufacturers of DCM-based paint strippers for whom the alternatives market may be even more important.

In summary, impacts on trade and competition are not expected to be damaging even if there may be significant changes in the internal market. It may also open up the market to some SMEs who have invested significantly in exploring the potential for alternative paint strippers.

9. RECOMMENDED RISK REDUCTION STRATEGY

9.1 Recommended Risk Reduction Measure

Based on the analysis presented in the previous sections, the recommended risk reduction measure is set as follows:

Recommendation

To consider at Community level, marketing and use restrictions under Council Directive 76/769/EEC (Marketing and Use Directive) on **all uses of DCM-based paint strippers, unless used in industrial installations under strictly controlled conditions**. The strictly controlled conditions require that:

a) fluororubber gloves must be used during all paint stripping activities;

b) effective local exhaust ventilation and mechanical ventilation (e.g. a fan) should be installed to provide make up air (where this takes into account, existing occupational exposure limits under Directive 98/24/EC) OR an independent air supply respiratory equipment must be worn at all times; and

c) the sides and top of all dip tanks should be enclosed and a separate ventilated area provided for drying finished articles.

Notes:

a) *Industrial installation refers to a permanent stationary technical unit where paint stripping activities are undertaken (for instance, metal stripping, furniture stripping, aircraft stripping, etc.). This term includes factories, workshops and other similar installations.*

b) *Section 4.9 of this report has discussed at length the issue of gloves. Although there is limited doubt that fluororubber gloves offer the best possible protection when using DCM-based paint strippers, there is an issue regarding the rate of replacement of the gloves. While laboratory tests indicate a breakthrough time of 150 minutes, this period may not be the most appropriate for setting a legislative requirement for periodic glove replacement. Factors that need to be accounted for include the nature and duration of paint stripping operations, the mechanical stress during use, the effect of sweat and the behaviour of the user. As shown in Section 4.9.5, it is not possible to specify a replacement rate for gloves used with DCM-based paint strippers. The employers should contact their glove suppliers to inform them of their working practices and the composition of the formulations they intend to use, and to obtain advice on the rate at which the gloves should be replaced.*

c) *Independent air supply respirator is a breathing apparatus that provides breathing air from a source independent of the surrounding atmosphere used (e.g. fresh-air or compressed-air equipment).*

9.2 Summary Justification for Recommended Risk Reduction Measures

9.2.1 Industrial Uses

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) were as follows:

A1. Total prohibition (ban) on all industrial uses of DCM-based paint strippers.

A2. Prohibition (ban) on all industrial uses of DCM-based paint strippers unless used in strictly controlled conditions.

A4. Prohibition (ban) of all industrial uses of DCM-based paint strippers unless appropriate personal protective equipment is used.

Our recommendation is based on Measure A2 for the following reasons.

The available information on accidents involving the use of DCM-based paint strippers suggests that most fatalities in Europe have occurred in industrial settings, with **poor ventilation** and the **use of (open) dip tanks** as a recurring feature of these accidents. Any recommended risk reduction measure should aim at ensuring a reduction in such DCM-related incidents.

Taking into account, (a) the potentially significant socio-economic impacts (particularly for SMEs) of an abrupt and total restriction on industrial uses of DCM-based paint strippers; and (b) the existing worker and environmental protection legislation (including legislation in the pipeline (e.g. REACH), it is considered that ensuring industrial use of DCM-based paint strippers under "*strictly controlled conditions*" (Measure A2) should be sufficient for minimising the relevant risks. The existing legislative framework and the stationary nature of the operations mean that there can be a reasonable degree of confidence that the implementation and monitoring of the strictly controlled conditions of operation will be successful. Moreover, companies involved in industrial uses may be better positioned to successfully address issues of health and safety of employees in comparison to other users.

9.2.2 Professional Uses

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) are as follows:

B1. Total prohibition (ban) on all professional uses of DCM-based paint strippers.

B2. Prohibition (ban) on all professional uses of DCM-based paint strippers unless used in strictly controlled conditions.

B4. Prohibition (ban) of all professional uses of DCM-based paint strippers unless appropriate personal protective equipment is used.

Our recommendation is based on Measure B1 for the following reasons.

The analysis undertaken for this study indicates that there is great variability in risk management practices during professional use of DCM-based paint strippers. Consultation with various stakeholders has highlighted a number of key issues.

- ***Lack of enforcement***: current enforcement practices are inherently inadequate, especially due to the large number, small size and mobile nature of the enterprises involved (where these enterprises are often individuals who work alone and/or are self-employed). The actual relevance of OELs to those using DCM-based paint strippers in professional uses is also limited (due to their widely varying working conditions) and the ability of users to measure the exposure levels is practically non-existent. More significantly, competent authorities do not appear to have the human and financial resources required (nor make it a priority) to monitor such uses. As a result, implementation and monitoring of a measure such as Measure B4 would probably add very little to the current situation and its monitoring would be very difficult.

- ***Non-compliance with legislation***: the users' knowledge of how to properly assess the risks (as required under Directive 98/24/EC) before using DCM-based paint strippers is limited and patchy. Consultation with companies involved in professional uses indicates that risk assessments are hardly undertaken for jobs that are considered 'small and quick'. In addition, most SMEs are unlikely to employ a dedicated health and safety manager. Only larger companies (for instance, companies sub-contracted to large public sector organisations, engineering companies with their own Health & Safety divisions, etc.) may be more inclined (or required), well equipped and knowledgeable to undertake a proper evaluation of the risks at all times as issues of liability and insurance are (more) important.

- ***Ignorance regarding appropriate risk management***: the use of engineering controls and especially PPE is very often inappropriate and inadequate. It is unlikely that the appropriate engineering controls would be used in the absence of a proper risk assessment (although, admittedly, in some cases it may be immediately clear whether engineering controls are needed and what these should be). While there are several types of gloves being used by those involved in professional uses, there is little evidence of the actual use of fluororubber gloves (which are generally considered to the most appropriate for the identified risks). Another example can be found in the use of visors for the protection of the operator's face. These offer limited respiratory protection and the visors are occasionally removed by operators because they are uncomfortable[57].

  Risk management practices are also hindered by inconsistencies in the information provided by suppliers. There appears to be no consensus amongst manufacturers,

57 Consultation indicates that professional users sometimes find the lack (or non-use) of a mask as a better risk management measure because this allows them to smell DCM in the air and be alerted to high concentrations. This practice does not, however, reflect the fact that DCM only becomes detectable to the human nose at concentrations well above the highest established national OELs.

authorities and users across the EU regarding what gloves and respiratory equipment may be appropriate and for how long. Hence, users are in general not provided with accurate, harmonised and/or up-to-date information on the hazards, risks and appropriate risk reduction measures (especially PPE) when working with DCM-based paint strippers.

- ***Poor risk perception***: Many users may only undertake occasional paint stripping work and they may purchase their materials from a DIY retail outlet as a consumer. This has two key implications: (a) these users have access to the same level of (limited) information (and safety requirements) as the consumer, and (b) the purchase of DCM-based paint strippers alongside consumers undermines the perception of risk when using the same product in the workplace. Also, tradesmen tend to rely on their 'long working experience' with DCM-based paint strippers as evidence for knowledge of risks.

- ***Market issues***: it is generally difficult (if not, impossible) to distinguish between consumers and professionals at the point of sale. Therefore, any measures (particularly restrictions) applied to consumers should also ideally apply to those involved in professional uses for practical and enforcement reasons.

We have considered whether a measure such as Measure B2 would be an appropriate option for risk management. Our conclusion is that, overall, requiring the professional use of DCM-based paint strippers to take place only under *strictly controlled conditions* would be impractical and unrealistic for the following reasons:

- measures relating to dip tanks are of no relevance to professional uses;

- ensuring that there is "effective" ventilation is impractical since, for professional uses, employees usually do not have the knowledge and/or the necessary equipment to achieve that (or to measure compliance against OELs);

- the use of fluororubber gloves (as well as independent air-supply respirators) for several of delicate applications that a decorator may undertake could make the use of the paint stripper very uncomfortable and difficult. More generally, it is unrealistic (taking into account the profit margins for these companies) to expect that users would be willing to use independent air-supply respirators and thick fluororubber gloves, as required by the proposed restrictions;

- as indicated earlier, the vast majority of companies involved are SMEs, and may in fact be micro-enterprises, which are very unlikely to employ a Health and Safety expert who might be able to provide appropriate and consistent advice and to monitor closely the practices of other employees; and

- the mobile nature of professional uses provides little reassurance for effective monitoring and enforcement of such strictly controlled conditions.

As a result of the above, and taking into consideration the analysis of the costs of a restriction as outlined in Section 8, Measure B1 (total ban on professional uses of DCM-based paint strippers) is considered to be the most appropriate option.

9.2.3 Consumer Uses

The measures that remained under consideration following the analysis in Section 7 (see Table 7.1) were the following:

C1. Total prohibition on all consumer uses of DCM-based paint strippers

C4. Prohibition on sales of DCM-based paint strippers unless sold along with appropriate PPE

Our recommendation is based on Measure C1 for the reasons that follow.

Consumers are offered and use the same DCM-based product as the companies involved in professional uses, however:

- they are not provided with the same amount of information and/or training (which, in any case, is currently inadequate);
- they are not subject to the same regulatory requirements, inspections or reporting requirements (in cases of accidents) and are, in particular, not required to undertake a proper evaluation of the risks (which, in any case, they are not best placed to undertake);
- they do not have access to the same equipment (especially engineering controls) as those involved in professional uses. In some cases, the working conditions at home may be much worse than those for tradesmen (for example, paint stripping may be undertaken in a basement, or an enclosed area with closed windows, due to bad weather, or in the presence of vulnerable persons such as children, elderly relatives or those with health conditions); and
- the correct PPE is disproportionately costly for consumers (and as, such, despite its advantages, it is not possible to recommend a prohibition on sales of DCM-based paint strippers unless sold along with appropriate PPE). In addition, authorities would not be able to enforce restrictions on consumers.

As a result of the above, and taking into account the fact that alternatives are available and their use is likely to result in small if any economic impact to the consumer (see analysis in Section 8.6), our recommendation is that the consumer uses of DCM-based paint strippers are banned.

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