European Commission, Brussels

Effectiveness of vapour retardants in reducing risks to human health from paint strippers containing dichloromethane

FINAL REPORT

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ETVAREAD

Expert Team for Vapour Retarding Additives

CONTENT

1 Background and objectives

Dichloromethane is a chlorinated solvent with a vapour pressure of 460,9 mbar (20°C). It is known to be one of the strongest paint strippers available in common use. However, due to its dangerous properties the application of DCM underlies several national and European regulations[1].

At present there is a controversial political discussion ongoing on the advantages and drawbacks of DCM-containing paint strippers and necessary restrictions on their use and marketing.

The controversial debate on DCM-containing paint removers and façade strippers is ongoing since more than a decade. In particular what concerns potential health effects, there are contradictory standpoints and interests in the debate. The discussion is to a certain extend missing scientifically based facts and evaluations to come to further decisions.

According to statements from producers of DCM and formulators of DCM-containing products, high quality products contain efficient vapour retarding additives. These vapour retardants would optimise on the one hand the paint stripping performance and on the other hand reduce the exposure to DCM to safe limits during the use of vapour retarded DCM-containing products. As a consequence restrictions for marketing and use of vapour retarded products are considered to be not justified.

According to statements from other stakeholders DCM-free substitutes are available and their use is technically and economically viable (or even advantageous) whereas the use of DCM-containing products is related to considerable health risks which even leads to fatal accidents due to the use of such products. A widespread opinion is therefore that the health risks can not be prevented by restrictions only relating to necessary vapour retardation.

Against this background it is the aim of the study to assess the risks to health related to the use of defined vapour retarded DCM-containing paint strippers. It is important to gather and evaluate recent scientific information on vapour retarding additives. Their performance shall be investigated in order to evaluate their effectiveness in reducing exposure to DCM during paint stripping. The dependence of DCM release from a representative selection of different formulations of paint strippers is investigated.

[1] e.g.
- Council Directive 96/49/EC of 23 July 1996 with regard to the transport of dangerous goods by rail
- Council Directive 90/517/EEC of 9 October 1990 adapting to technical progress for the 11th time Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances
- Commission decision 2000/532/EC related to a list of hazardous waste

The study provides a scientific basis for a possible proposal of the European Commission for restrictions on the marketing and use of DCM-based paint strippers in the framework of Directive 76/769/EEC on the marketing and use of certain dangerous substances and preparations.

2 Project approach

To meet the project requirements and reach the mentioned objectives the following points have been considered within the project approach:

- European market situation, properties, grade of vapour retardation and performance of paint strippers (see chapter 3); this chapter and the corresponding annex also contains information on DCM free strippers

- the quantitative release of DCM from different vapour retarded paint strippers (results of own laboratory test; see chapter 4); this chapter also includes tests done by other institutions and compares different results

- the health effects of DCM which is released in the air during the application of the paint stripper (see chapter 5);

- an overall integrated appraisal of different types of paint strippers with regard to their health effects (see chapter 6); this chapter again contains some information on health effects of DCM free strippers

- the fatal accidents attributed to the use of DCM-containing paint strippers (see chapter 7);

- possible conditions and product properties of vapour retarded DCM-based paint stripper that can reduce health risks (see chapters 8 and 9);

- conclusions and recommendations with respect to possible restrictions on the marketing and use of DCM containing paint strippers (see chapter 9).

Chapter 10 contains a list of references.

Additional material and contributions to the subject is provided in the Annex (chapter 11).

In order to lead the ongoing controversial discussion back to a technical and scientific background one principal idea behind the project approach was to carry out reproducible laboratory test that are accepted by both, promoters and objectors to DCM containing paint strippers.

The project team is convinced that such tests are essential to get reliable results and progress in the controversial discussion and therefore included the performance of laboratory tests in the project approach in order to achieve the project objectives. To this end a test design has been developed and discussed with the stakeholders prior to the realisation of the laboratory tests.

The results of the tests allow conclusions related to the risks related to the use of DCM containing paint strippers. The test design and the resulting conclusions have been discussed and agreed with several stakeholders before the tests have been realised. After presenting preliminary results to Member States it was mentioned that broader tests would be required to cover also worst case conditions for the application of DCM containing paint strippers. The project team appreciates this proposal, however, due to available resources this was not possible within the scope of the project to provide data on measurements of worst case conditions. However, the test result are extrapolated to worst case conditions. Information on tests realised by other institutions are also included in the final report and are compared to own test results (see chapter4).

During discussions with various stakeholders it was mentioned that a comparison between the risks related to DCM containing and DCM free paint strippers is necessary. The project team agrees that such information is helpful but again this task was not required in the technical annex. However, the project team has collected information on DCM free alternatives and this information is included in the report.

It has to be stated clearly that it was not the intention of this project to elaborate an exhaustive comparison (including technical, health, environmental and economic aspects) between all types of paint strippers.

3 Market survey

3.1 Market demands in paint stripping

Paint removal in the form of paint stripping or façade stripping is an essential process before further working steps in particular in painting works, elimination of graffities, restoration of buildings or antique furniture. Beside mechanical and thermal paint removal techniques, chemical paint removers are often an appropriate means to be applied.

The following criteria describe the market demands to chemical paint removing products

- Low costs
  Including product price, costs for disposal, health and safety protection measures (e.g. air suction, breathing air supply, gants)
- Stripping speed
  A fast stripping speed is typically seen as an advantage
- Low labour intensity
  Depending on the product performance and its application in one work cycle a different amount or thickness of paint layers can be removed per work cycle.
- High effectiveness for specific coating systems
  There are significant differences between chemical paint removers and their efficiency when it comes to remove specific coating systems
- Damage to the substrate
  In particular when paint is removed from valuable objects an important criterion for paint removers is that the substrate is not damaged by the paint remover or the application procedure
- Easy to handle
  The handling is to a far degree determined by the personal protection measures that have to be taken for the paint removing procedure
- Low health risk
  Chemical paint removers are frequently correlated with specific health risks due to chemical substances with specific effects on human health
- Safety risk
  Some chemical paint removers may pose a certain safety risk in particular due to their sometimes high flammability

3.2 Overview on existing DCM-containing products and share of vapour retarded products

The following table gives an overview on the relative importance of produced DCM for the use in paint remover markets in western European countries

Market	tons	share
Benelux	2956	0,17
UK/Eire	4267	0,24
FR	4779	0,27
DE	1067	0,06
ES	2203	0,12
IT	1532	0,09
Other Western European Countries*	1056	0,06
Total	17860	1

*Austria, Switzerland, Denmark, Finland, Greece, Turkey, Portugal, Sweden, Norway

Table 3-1: Importance of EU markets for DCM in paint removing products

In addition to the produced DCM a big amount of recycled DCM is used for paint strippers. In some countries like Germany the amount of recycled DCM is far more important than the amount of produced DCM. The recycled DCM mainly comes from the pharmaceutical industry where DCM is used for extraction purposes. It is difficult to get figures on the amounts of recycled DCM but a rough estimation leads to a range of 8.000 to 12.000 tons.

Assuming an average content of 75 to 80% of DCM in paint removing products, the total amount of 17.860 M tons corresponds to approximately 22.000 to 24.000 M tons of paint removing products from new produced DCM and 10.000 to 15.000 M tons of recycled DCM.

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). This shows that on a formulation basis the product diversity per country is comparatively low.

The units in which DCM containing paint removers are sold are dominated by 500 ml and 1000 ml units. Figure 1 shows a differentiation of sales for containment units at the UK DIY market. As the figure demonstrates, the most important amounts at the U.K. DIY market are sold in 1 liter containments. Formulators of paint strippers have stated that a restriction of the marketing for the DIY market to 500 ml containments would lead to significantly lower sales volumes and thus severely affect the DIY market of DCM containing paint removers.

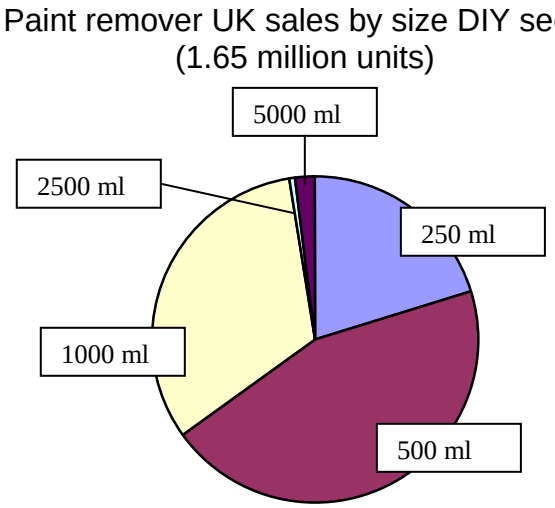


Figure 1: Differentiation of sales for containment units at the UK DIY market for DCM containing paint removers (source: UK industry, 2003)

According to expert statements the use of vapour retardants has started in the 1960ies and has fine tuned over the years. Nowadays the use of vapour retardants is state of the art and all products that are nowadays available at the market are vapour retarded. However there are significant differences of the efficiency of vapour retardation.

3.3 Properties and performance of vapour retarded DCM containing strippers

A typical formulation of vapour retarded paint strippers is shown in Table 3-2:

Component	%
Dichloromethane	75 to 90
Methanol/Ethanol	0 to 10
Extenders	0 to 20
Thickener	0 to 2
Surfactants	0 to 2
Corrosion inhibitors	0 to 2
Vapour retardants*	0 to 4

* in particular waxes or paraffins

Table 3-2: typical formulation of vapour retarded paint strippers

Some DCM containing paint strippers contain only ~ 50% of DCM. Some DCM containing paint strippers contain dangerous substances, such as propan-2-ol in concentrations above 10 and below 20% (Xi, R36 and R67), 1-methoxy-2-propanol (R10) or 2-methylpropan-1-ol (R10, R37/38, R41, R67) in concentrations below 3%.

3.4 Properties of DCM free products

Typically used solvents in DCM free products are di-glycol-ethers, di-basic ester, solvent naphta and n-methyl-pyrrolidone.

The Technical Rules for Hazardous Substances 612 [TRGS 612 2002] on “Substitute materials, substitute techniques and applications limitations for methylene chloride paint stripping agents” contains proposals regarding the use of substitute substances, substitute techniques and limitations on the use of methylene chloride in its use in paint stripping agents.

Consideration is given only to those ingredients which are used on account of their effect as paint stripping agent or as co-solvent. Other additives, such as tensides and emulsifiers, are not considered. Table 3-3 and Table 3-4 list these substances contained in paint strippers for whose percentage content in DCM free paint strippers exceeds 5%. The information is based on German experiences and is not necessarily representative for Europe.

Substance name	CAS-Nr.	Concentrations reported in selected safety data sheets
di-basic ester (DBE)	-	
2-methoxymethylethoxy)propanol	34590-94-8	
2-(2-butoxyethoxy)ethanol*	112-34-5	
n-methyl-2-pyrrolidone (NMP)	872-50-4	
ethyl 3-ethoxypropionate (EEP)	763-69-9	
solvent naphtha light to heavy	-	
solvent naphta, de-aromatised	-	
methyl decanoate	110-42-9	50 - 100
2-ethylhexyl acetate	103-09-3	
fatty acid methyl ester (C8 to C14)	-	
alkyl-acetate (C6 to C13)	-	
3-methoxybutyl acetate	4435-53-4	
2-(2-ethoxyethoxy)ethanol	111-90-0	

Table 3-3: Substances contained in DCM free paint strippers for indoor and outdoor big surface area paint stripping works (facade strippers) [TRGS 612 2002 and producer informations]
* only relevant in very few products

Substance name	CAS-Nr.	Concentrations reported in selected safety data sheets
1-methoxypropan-2-ol	107-98-2	
n-butyl acetate	123-86-4	10 - 25
dimethyl sulfoxide (DMSO)	67-68-5	10 – 25
acetone	67-64-1	10 - 25
benzyl formate	104-57-4	
1,3-dioxolane	646-06-0	
2-methoxy-1-methylethyl acetate	108-65-6	
benzyl alcohol	100-51-6	25 - 100
2-(2-butoxyethoxy)ethyl acetate	124-17-4	
tetrahydrofuran (THF)	109-99-9	
2-butoxyethanol	111-76-2	
heptan-2-one	110-43-0	
gamma-butyrolactone (G)	96-48-0	
2-methylpropan-1-ol (G)	78-83-1	
dipentene (G)	138-86-3	

Table 3-4: Substances contained in DCM free varnish strippers (in addition to those listed in Table 3-3; G: only contained in graffiti-removers) [TRGS 612 2002 and producer informations]

The following tables show typical compositions for DCM free paint removers. Again it has to be stated that the information is based on German experiences and is not necessarily representative for Europe:

Component	%
2-methoxymethylethoxypropanol	10 to 20
n-methyl-2-pyrrolidone	5 to 10
di-basic ester (DBE)	60 to 70
thickener, tenside	~ 10

Table 3-5: Typical composition of facade strippers [Rühl 2003]

Component	%
di-basic ester (DBE)	70
n-methyl-2-pyrrolidone	20
thickener, tenside, organic acids	10

Table 3-6: Typical composition of paint removers for oil-paints, varnishes, alkyd resins and thick layer glazers [Rühl 2003]

Component	%
benzyl alcohol	30 – 40
water	35 – 55
peroxide	2 – 5
organic acid	2 –5
emulsifier, tenside, thickener	~ 15

Table 3-7: Typical composition of paint removers for 2-K paints and stove-enamels [Rühl 2003]

Component	%
di-basic ester (DBE)	50
gamma-butyrolactone	15
n-methyl-2-pyrrolidone	25
organic acid, thickener, tenside	10

Table 3-8: Typical composition 1 of graffity removers [Rühl 2003]

Component	%
di-basic ester (DBE)	25 – 40
n-methyl-2-pyrrolidone	20 – 30
2-methoxymethylethoxy)propanol	10 – 20
dipentene	15 – 30
thickener, tenside	4 – 10

Table 3-9: Typical composition 2 of graffity removers [Rühl, 2003]

A UK -product which (according to the producer) “has a CE mark for safety for use as a children’s toy, yet still is effective to be used widely by the consumer, the professional and industrial user” contains according to analyses realised by competitors among other di-basic ester (dimethyladipate~ 19%, cas-no 627-93-0, not classified in the Annex I of Directive 67/548/EEC; Germany: WGK 1 = slightly water endangering, repeated or prolonged exposure → blurred vision [Bégin 1999]; vapours may form explosive mixture with air; Swiss toxic list category 4) and triethylphosphate ~ 11%, cas-no 78-40-0, labelling Xn, R22). The paint stripping performance is according to the producer very good, according to competitors and some clients not satisfying.

At present the formulations of some DCM free strippers seem to change. NMP is under discussion at the EU working group on classification and labelling. The group has proposed to classify it in the following way:

- Xi, R36/37/38 (irritant to eyes, respiratory tract and skin)
- T, R 61 (may cause harm to the unborn child)

The decision related to this classification is pending. Following information of a major producer of DCM free paint strippers in Germany NMP will be replaced in its most important stripper due to the expected new classification of NMP (actual classification: Xi, R36/38). There is no information by which substance NMP shall be substituted.

3.5 Comparison of the performance of strippers

Table 3-10 shows a comparison of the market relevant properties of DCM-containing vapour retarded products versus DCM-free products on the basis of the above mentioned market criteria.

Criteria	DCM-containing	DCM-free	Note
costs	contradictory	contradictory	The product price of DCM-containing products is lower. An overall evaluation of the costs considering disposal, health protection measures etc. leads to contradictory results according to the variation of the evaluation parameters (costs for disposal, gants, breathing air supply, …)
stripping speed	fast	slow in many cases	slow stripping speed may be seen as an advantage or disadvantage according to the situation of the work flow in some cases
labour intensity	contradictory	contradictory	according to contradictory statements the stripping of several layers during one flow of work is stated as an advantage for each of the product types
effectiveness for specific coating systems	typically high	can be a problem in selected cases	According to several statements DCM-free products have low performance for selected coating systems. On the other hand it is stated that specific DCM-free products are available for all coating systems. Producers of DCM free products provide “test boxes” that allow to treat test surfaces for the selection of the optimum product and to plan and calculate stripping works even if the paint system is not known
damage to the substrate	low	can be a problem in selected cases	due to the high evaporation rate DCM remains for less time on and inside the substrate which may be important in selected cases where sensible substrate is below the paint to be removed (e.g. in specific restoration applications)
Handling	might be difficult	might be more convenient	generally more convenient personal protection required when using DCM-free products
health and safety risk	contradictory	contradictory	several evaluations estimate a lower risk for DCM-free products; however on the other hand there are statements giving evidence for health risk due to • increased use of other organic solvents and the risk of increased mortality due to solvent abuse of VOC in products • often higher flammability of DCM-free products and related accidents • open questions with respect to possible health effects due to exposure to components of DCM free components

Table 3-10: Market demand criteria compared for DCM-free and DCM-containing paint removing products

The information is derived from literature and specifications from both, producers of DCM containing as well from producers of DCM free paint removers. The trueness of the statements on the performance can not always be verified.

The following statements on the performance of paint strippers have been brought into the discussion from producers and advocates of DCM free products:

- *"Our DCM-free products are lower in cost, as fast as DCM strippers (although we should add be used in a different way to DCM products)."*
- *"Due to very little evaporation our products are considerably less labour-intensive than DCM products. With reference to specific coatings systems, our products will remove as many, if not more, coating systems than DCM. DCM will not remove water-based, water-borne, or emulsion type coatings."*
- *"Damage to the substrate is not caused by either DCM or DCM-free products except for highly alkali or acidic products. Most damage to substrates in stripping is done by stripping tools and/or the operative!"*
- *"There are DCM-free paint removers which pose a health risk – but not all"*

The following statements on the performance of paint strippers have been brought into the discussion from producers and advocates of DCM containing products:

- *"DCM based paint removers are fast acting, universal and high performing for almost all types of paints including 2 component systems and car paints, not damaging substrate surfaces, available at low costs, non corrosive, acid and alkali free, non flammable"*
- *"DCM free paint removers are slowly acting, expensive, can damage substrate surfaces, low effective on alkyd and 2 component systems and car paints"*

To conclude, the market demands for paint removing activities are quite diverse and there is no general answer possible which product types (DCM-containing or DCM-free) are more appropriate to satisfy the demands in each single application.

In this context it is important to note that the market demands in Member states are quite diverse due to different dominating applications. According to experts on the most important European market, the U.K., the predominant paint stripping task is the application to wood and in particular to external wooden house entrance doors and wooden interior. In contrast to this, in France and Germany the paint removal from external facades and internal walls seems to be the most important field of use.

Both, DCM containing and DCM-free substitutes seem to be available for almost every paint removing task even though their use may sometimes be related to specific disadvantages.

3.6 Market trends

The use of DCM for several applications has gradually declined since the mid 80^{ies} (~ 200 kt/a) to the mid 90^{ies} (~ 140 kt/a). Since then the use is more or less stable. In 2002 ~ 140 kt have been used in the EU Member States plus Norway and Turkey. The total EU production is about 240 kt/a with an export amount of ~ 100 kt/a. This production is covered by 7 European producers that are listed in Table 3-11.

Company	Country	Products
Aragonesas SA	ES	DCM
Atofina SA	FR	DCM, TCE, PCE
Dow Europe SA	SUI	DCM, TCE, PCE
Ercros SA	ES	DCM, PCE
Ineos Chlor Ltd	UK	DCM, TCE, PCE
LII Europe GmbH	DE	DCM
Solvay SA	BE	DCM, TCE, PCE

Table 3-11: DCM producing companies in Europe

The current use of produced DCM sold for paint strippers is 17.860 kt (year 2002; see Table 3-1).

Market	Sales in 2002	Index referring to 2001	Share
Benelux	2956	152	0,17
UK/Eire	4267	93	0,24
FR	4779	90	0,27
DE	1067	81	0,06
ES	2203	101	0,12
IT	1532	95	0,09
Other WE	1056	81	0,06
Total	17860	98	1

Table 3-12: Importance and trends of EU markets: sales for DCM in paint stripping products in tons [source: ECSA 2003]

Table 3-12 demonstrates with an index referring to 2001 the trend in sales of pure DCM that has been produced for the formulation of paint stripping products in 2002. Trends in the production of paint strippers on the basis of recycled DCM are not available.

According to statements from producers and formulators of DCM-free products, the sales of DCM-free products are steadily increasing and DCM-free products are available in all Member States for all kinds of paint removing tasks.

4 Release of DCM from vapour retarded paint strippers by laboratory tests and previously reported test results

4.1 Collection and selection of products

Prior to the realisation of the laboratory tests, two important tasks have had to be fulfilled. First, the collection and selection of samples from the important European markets was carried out and second, the design for the laboratory tests has been specified.

For the collection and selection of samples, producers of DCM and formulators of paint stripping products have been contacted throughout Europe. Selected vapour retarded DCM-containing products have been send to the laboratory in Germany (see Annex, Table 11-1). The selection shall allow to assess the impact of vapour retarded DCM-containing products having in mind the “whole” background of paint stripping products.

At the laboratory reproducible tests for the simulation of different conditions of the application of DCM containing paint strippers have been carried out and correlated exposure of users to DCM via air has been measured. The laboratory tests have been concluded in November 2003.

The precise design of the laboratory tests has been elaborated by the project team and has been discussed and adjusted according to the input from several external experts. Having in mind the controversial discussion it was essential to establish a test design that finally has been agreed by the relevant stakeholders prior to the realisation of the laboratory tests. Thus a high acceptance of the results was assured.

4.2 Objective of laboratory tests

The laboratory tests were outlined according to the general objective to measure the release of DCM from paint removers. The test design shall allow to conclude on the quantitative release of DCM and the inhalative intake due to the use of paint removers and to compare

- the effectiveness of different vapour retarded paint removers during
  - application phase
  - effecting time
  - scratch-off phase
- the effectiveness of vapour retardation of paint removers applied on upright surfaces versus horizontal surfaces
- the effect on DCM evaporation due to the application of paint removers to painted versus not painted chipboards (alkyd resin)
- the effect on DCM evaporation due to the application to different surface areas
- the influence of different ventilation conditions

4.3 Test design:

- Test room volume: 2.5 x 2.5 x 2.4 m = 15 m^3
- Ventilation arrangement: at opposite sides of the room two openings are used for defined ventilation. Lower edge of the upper opening 1.5 m above ground. The lower edge of lower opening on the opposite side 10 cm above ground. The following view illustrates the arrangement of ventilation openings:

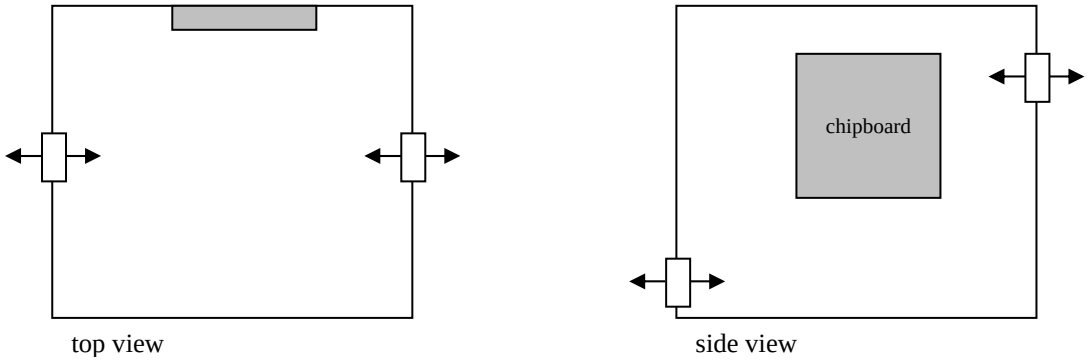


Figure 2: Arrangement of ventilation openings

- Ventilation: defined air volume exchange via the ventilation holes. Ventilation in separate trials in both directions (i.e. suction stream at the upper ventilation hole vs suction stream at the lower ventilation hole).
- Ventilation volume: air volume exchange in an average room of 15 m^3 = 60 m^3/h (standard ventilation condition). This is an air exchange rate of 4 which corresponds to a half opened window.
- Test surfaces: 1 m^2 chipboard (standard surface area)
- Defined amounts of paint stripper applied (350 ml)
- Temperature 17 to 20°C (monitoring during tests)
- Air humidity 40 to 65% relative humidity (monitoring during tests)
- Different paint strippers have been applied under defined conditions
  - procedure and time for painting (5 minutes as standard application time)
  - defined time to effect on the work piece (10 minutes as standard effecting time)
  - defined procedure and time for scratching and removal (10 minutes as standard removal time)

- Monitoring of DCM concentration in air:
  - During the whole application time (painting, effective time, removal) a monitor collects the air on a DCM active carbon test tube (precision of measurements up to ±30%). The monitor is arranged at a distance of approximately 80 cm sideways to the centre of the chipboard (see Figure 3). The result will be the average DCM concentration in air during the whole procedure.
  - At the same time an IR sensor (Miran 1A) registers continuously the concentration of DCM in the air (precision of measurements: ±25%, in praxis approximately ±15%). The IR sensor is installed at face level in the centre and defined distance (length of arm; ~ 80 cm) to the chipboard (see Figure 3).

  The continuous measurement enables to compare the effectiveness of different vapour retarded paint removers during the application phase, the effecting time and the scratch-off phase.

The following picture illustrate the arrangement of the test equipment:

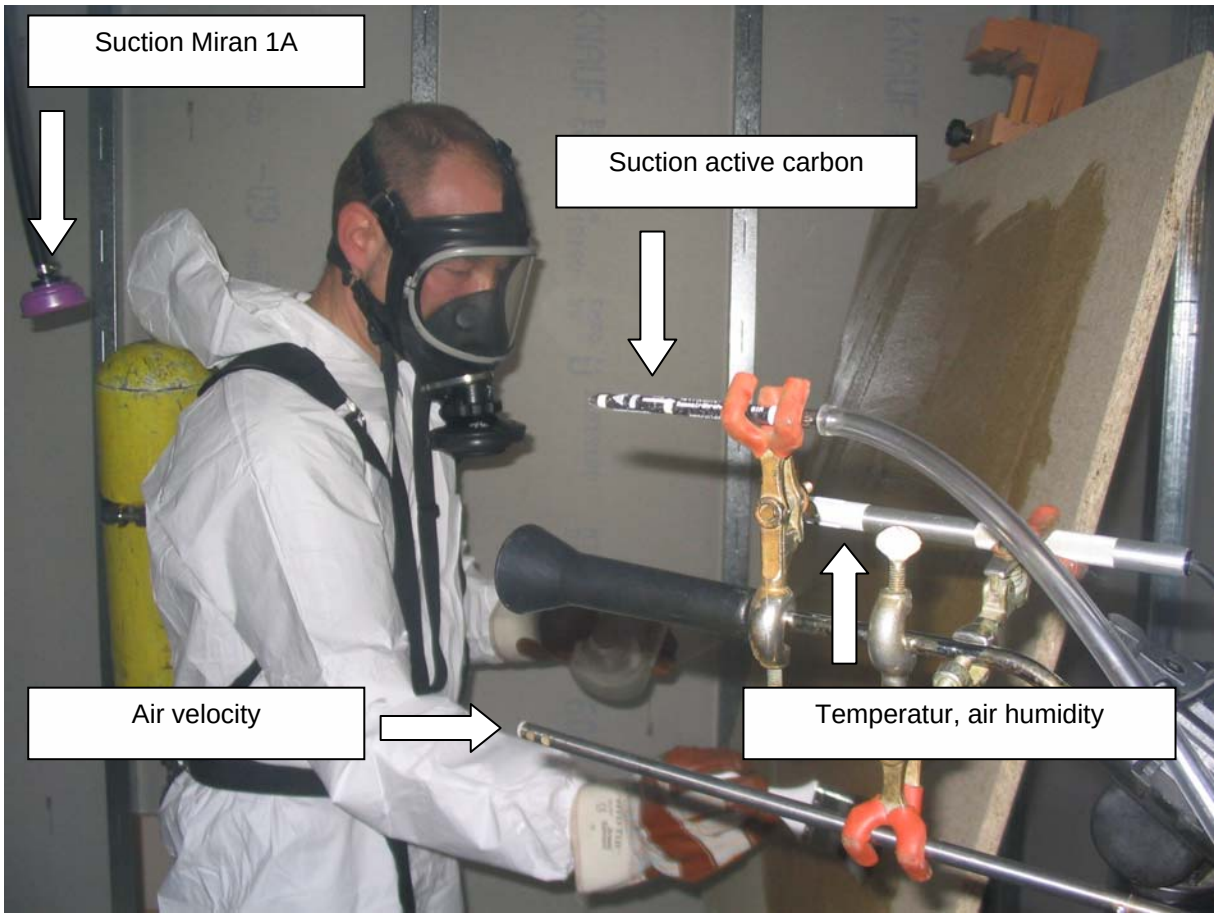


Figure 3: Arrangement of monitoring equipment (picture 1)

- Variations
  - 10 different products applied to upright plate boards at defined standard conditions (application procedure, ventilation, time, surface area, paint remover amount) in order to compare different products
  - 3 different time combinations (for application time, resting time, scratch-off time) with one product in order to show the influence of time variation
  - One application to a horizontal chipboard at defined usual time combination in order to compare application to upright and horizontal boards
  - One application to a painted chipboard (usual alkyd resin) at defined usual time combination in order to compare application to upright and horizontal boards
  - Three applications to varying surface areas (1.00 m², 0.50 m², 0.25 m²)
  - Three variations of ventilations
    - 60 m³/h, suction via upper ventilation hole
    - 90 m³/h, suction via upper ventilation hole
    - 60 m³/h, suction via lower ventilation hole

A precise test design and test programme can be found in the Annex under chapter 11.3.

4.4 Test results

A complete documentation of the test results can be found in the Annex under chapter 11.4. In the following the results are evaluated according to the objectives of the laboratory tests as listed in chapter 4.2. The values reported are mostly based on the results received from the evaluation of the active carbon tubes. Due to the equipment specific properties all the reported values have a guaranteed accuracy of ± 30%. According to experiences with the used active carbon tubes the result can be expected to have a significantly higher accuracy. However the graphical illustration of the results show ± 30% error bars.

The tests have been performed in two test series. Results from the first test series (with one exception suction stream for ventilation at the upper ventilation hole) are shown in yellow columns, those from the second series (suction stream for ventilation at the lower ventilation hole) are shown in blue columns.

4.4.1 DCM evaporation from different products

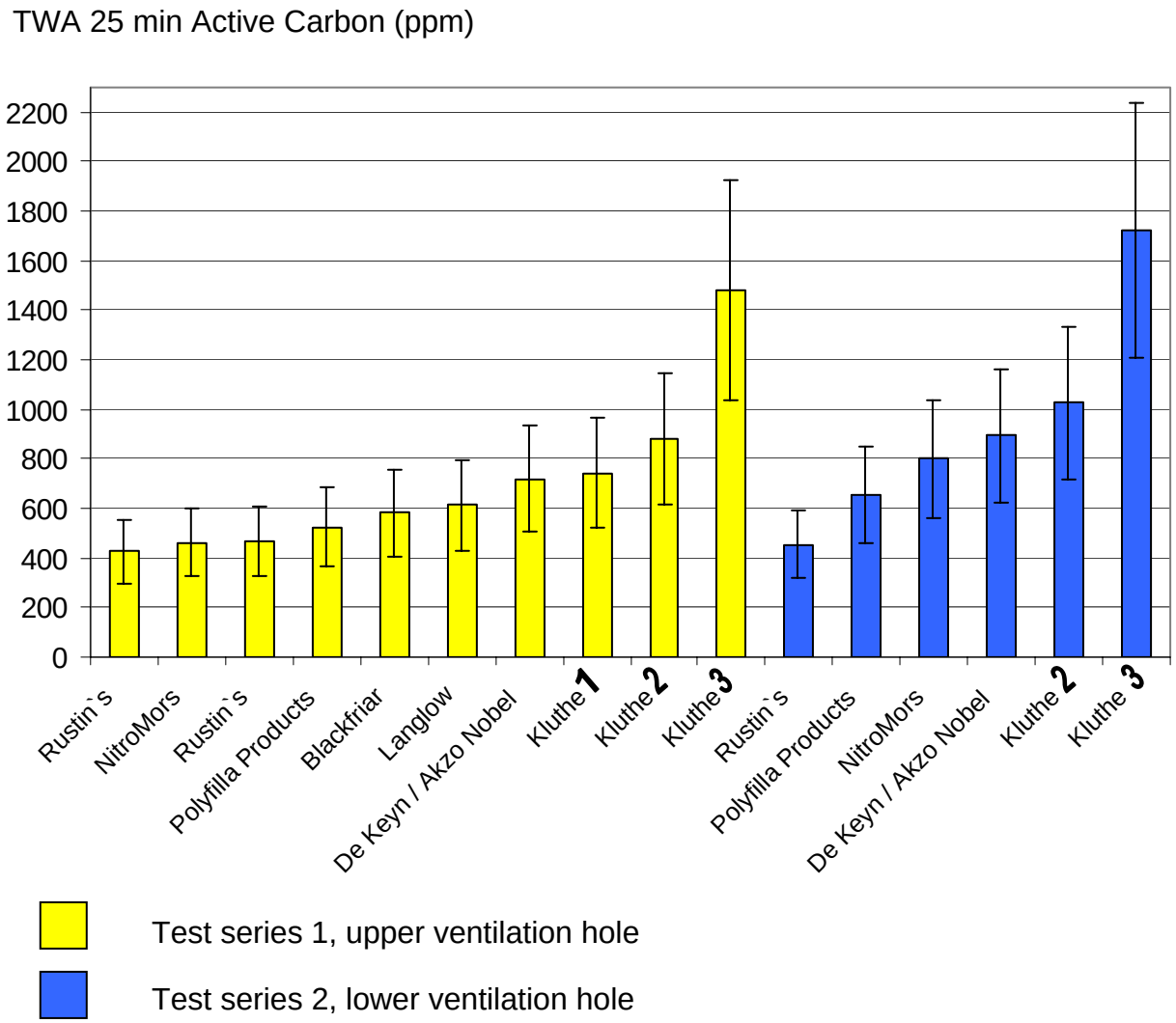


Figure 4: DCM evaporation from different paint removing products

The exposure values of vapour retarded products range from ~ 400 to ~ 1000 ppm TWA 25 min (time weighted average over 25 minutes). The last column of each test series represents a sample without vapour retardation. The corresponding exposure levels are ~ 1500 and ~ 1700 ppm respectively.

The 3 tested products of Kluthe clearly show the influence of vapour retardants. Kluthe 3 is a formulation without any vapour retardant. Kluthe 2 is a product containing a certain share of vapour retardant. Kluthe 1 contains twice the amount of the vapour retardant of Kluthe 2. Vapour retarded products lead to significantly lower exposure.

The direction of the air exchange flow does not have a significant influence on the exposure in the test room (small room).

The tests that are leading to the results shown in Figure 4 are based on a treated surface of one square meter. This area corresponds to the stripping of half a door on one side.

Conclusion

The conclusion of this test is:

- *A vapour retarded product lowers exposure significantly compared to a non vapour retarded product.*
- *Between the products available on the market, the product with the lowest exposure values leads to about half of the exposure values of the product with highest exposure levels; it is assumed that all DCM containing products that are available on the market are covered within this range.*
- *In a small room with low air exchange rate an effect of the direction of the air exchange flow is not expected.*

4.4.2 Effectiveness of vapour retardants

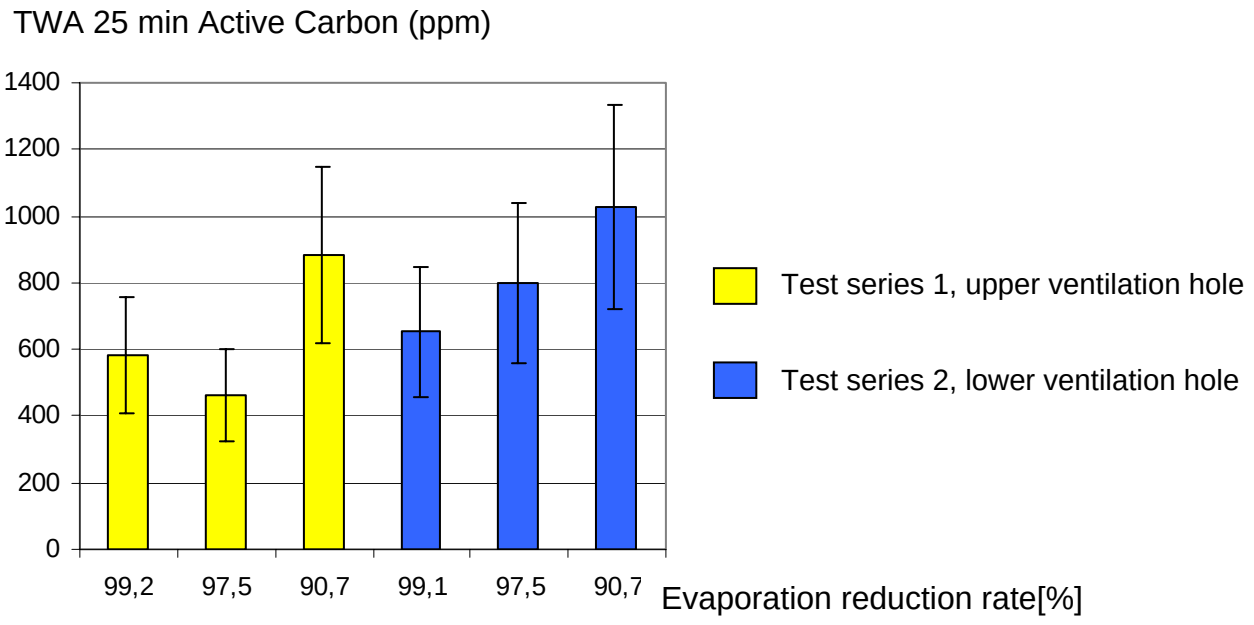


Figure 5: Effectiveness of vapour retardation

For some of the products the evaporation reduction rate[2] is known. Products with high evaporation reduction rate exhibit lower exposure levels. Paint removers with an evaporation reduction rate ≥ 95% lead to exposure values between 400 and 800 ppm which corresponds to exposure levels that are more than 50% reduced compared to those resulting from non-vapour retarded products (~1500 to 1700 ppm).

However, a higher evaporation reduction rate does not automatically lead to lower exposure rates. In the test a paint remover with an evaporation reduction rate of 99,2% showed higher exposure values than another with an evaporation reduction rate of 97,5%.

Conclusion

Vapour retardants with an evaporation reduction rate of more than 95% lead to lower exposure values than products with higher evaporation rates.

4.4.3 Evaporation during application, effecting, scratch off

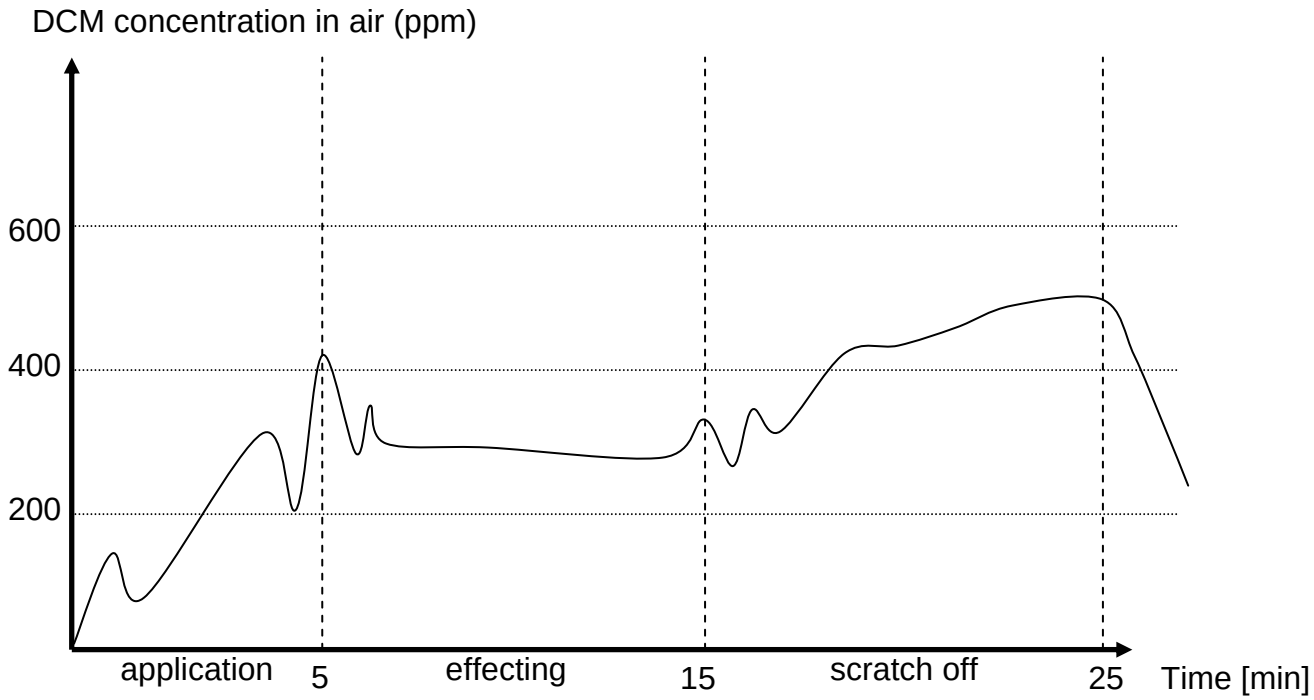


Figure 6: schematic trend of DCM concentration in air during application, effecting and scratch off phase based on measurement VP03 (average value over the time of 25 minutes ~317 ppm; see Annex section 11.4)

[2] determined according to test method "Rate of vaporisation of dichloromethane based paint removers" No 127/1; see Annex

The above graphic shows in a schematic form a typical trend during application, effecting and scratch off phase with an immediate increase of the DCM concentration in the air after the start of the application. A slight decrease during effecting and a further increase during the scratch off phase. The increase during application and scratch off can be explained with the effect of disturbance of the barrier which builds up at the surface of the applied paint remover by brushing or scratching. The barrier slows the evaporation of DCM. As soon as the barrier is disturbed, the evaporation of DCM increases and the DCM concentration in air increases.

The amounts of paint remover applied during the test have been weighed and dispensed from the original product containment into a small container outside the test room. During the activity of dispensing, which is part of the normal work flow, a first short peak in exposure levels can be expected due to the evaporation of DCM during dispensing. For reasons of comparability, the activity of dispensing is not taken into consideration in the test design. Taking the peak during dispensing into consideration the exposure levels expressed as time weighted average over 25 minutes may slightly increase. This would have to be confirmed by additional measurements.

The test design does not cover all application conditions. In particular in external façade stripping a common method to remove the paint (including the applied paint remover) after application and effecting is by hosing instead of scratching. On the basis of previously reported test results it can be concluded that during hosing the exposure values are also increasing (see Table 11-5). However, as the exposure values during hosing are usually lower compared to the values during application and scratching, hosing does not seem to be the critical phase.

Conclusion

Exposure levels peak during application and scratch off. During non-working phases exposure levels decrease.

4.4.4 Effect of application on upright vs horizontal surfaces

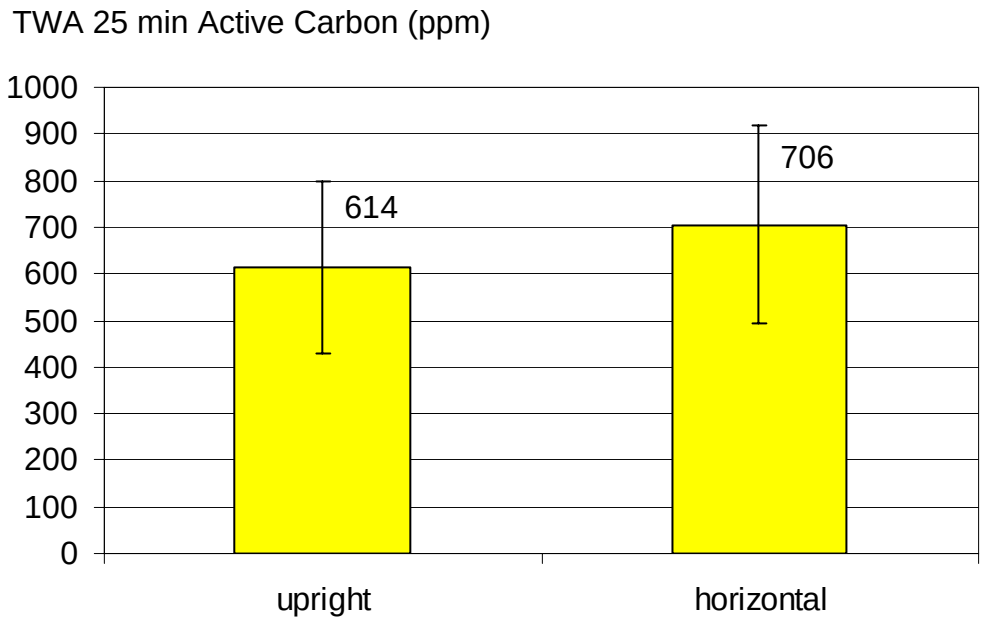


Figure 7: Effect of the application on upright and horizontal surfaces on DCM exposure

There have been assumptions that due to the run off of applied paint remover from upright surfaces the formation of a wax barrier is inhibited and as a consequence the efficiency of vapour retardation is disturbed. The test results demonstrate that vapour retardants are also efficient at upright surfaces and that there is no difference between the exposure levels related to the use of vapour retarded paint strippers on upright or horizontal surfaces.

Conclusion

There is no relevant difference in the efficiency of vapour retardation on upright or horizontal surfaces

4.4.5 Effect of application on painted vs non-painted surfaces

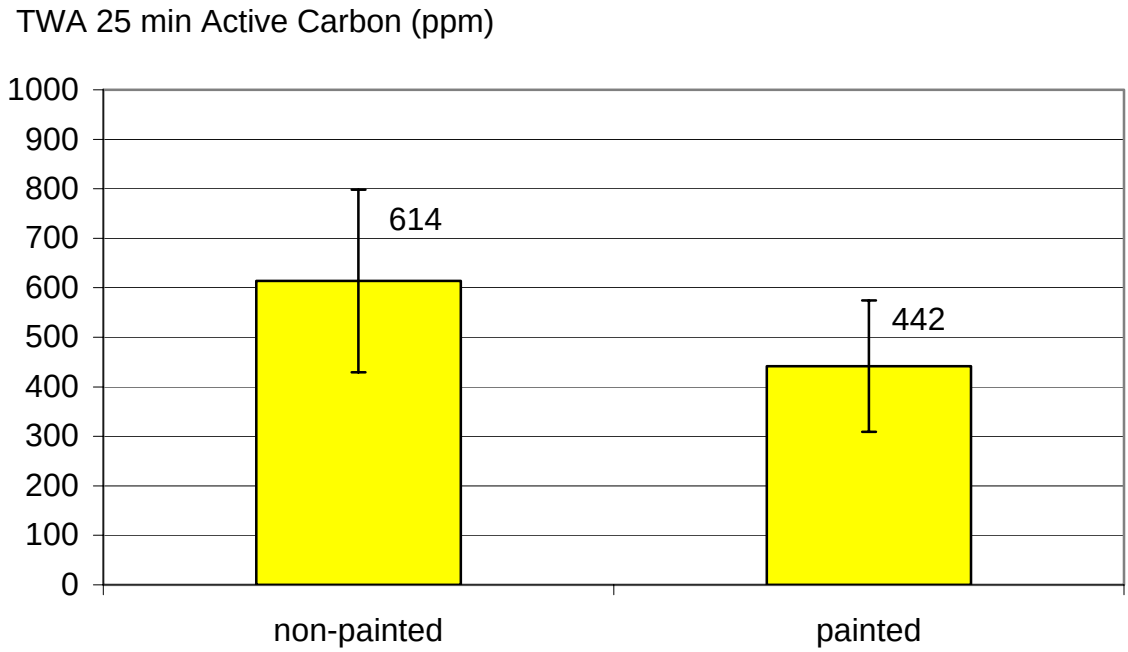


Figure 8: Effect of the application on non-painted and painted surfaces on DCM exposure

For reasons of practicability and reproducibility, the tests have been carried through on non-painted chipboard. One trial was performed on painted chipboard. The results may be interpreted in a way indicating somehow lower evaporation from painted work pieces. However, having in mind the limited accuracy of the measurements (±30%) and the limited amount of measurements assume that the evaporation of DCM from painted and non-painted surfaces can be regarded as comparable.

Conclusion:

Performing tests with a non painted surface does not show better results for DCM containing strippers compared to a painted surface. The influence of the parameter "paint" should not be overestimated for emissions.

4.4.6 Effect of surface area treated

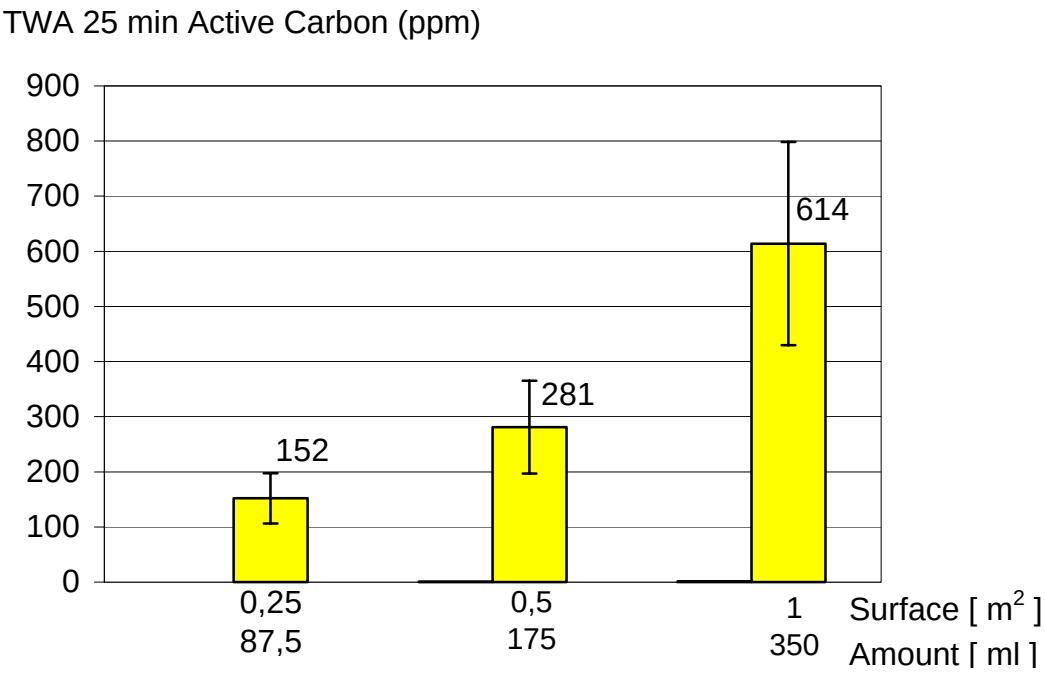


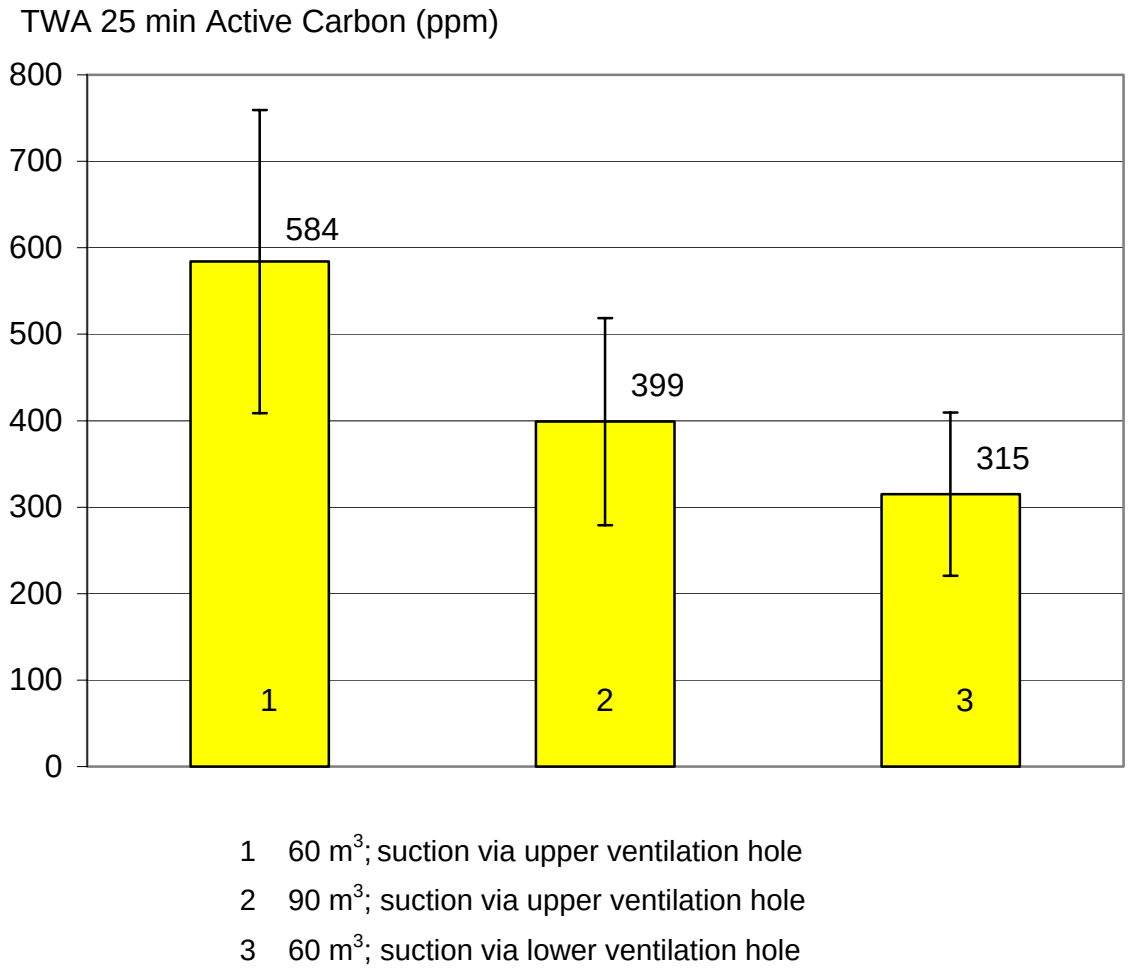
Figure 9: Effect of the application on non-painted and painted surfaces on DCM exposure

The above graphic shows an almost linear dependence of exposure levels from the corresponding surface area treated. In the tests performed and in praxis, the surface area is directly correlated to the amount of paint stripper applied. The graphic illustrates the results from an efficiently vapour retarded product. The exposure level for a surface area of 0.5 m^2 and 175 ml is about ½ of that related to 1 m^2 and 350 ml and correspondingly the level for a surface area of 0.25 m^2 and 87.5 ml is about ¼ of that related to 1 m^2. Exposure levels are approximately proportional to the surface treated and the amount used. This fact enables to extrapolate the test results to different application scenarios with varied amounts of paint remover applied.

Conclusion

The amount of stripper used has an almost linear influence on the exposure level and allows the extrapolation of the test result to different application scenarios.

4.4.7 Influence of different ventilation conditions



1 60 m^3; suction via upper ventilation hole

2 90 m^3; suction via upper ventilation hole

3 60 m^3; suction via lower ventilation hole

Figure 10: Effect of different ventilation conditions on DCM exposure (1)

As expected the ventilation conditions are an essential factor for the exposure levels. The standard ventilation conditions have been a suction stream of 60 m^3/h at the upper ventilation hole. This represents an air exchange rate of 4 (i.e. 4 times exchange of the room volume per hour) which corresponds under praxis conditions to a half opened window.

The Column no 1 in the above graph is related to the standard test ventilation conditions. The second column is related to an air exchange rate of 6 and shows that the exposure levels are decreasing with increasing ventilation. It can be assumed that an increase of the ventilation of 1/3 leads to a decrease of the exposure of approximately 1/3.

The column no 3 illustrates the exposure levels under the condition that the ventilation suction stream of 60 m^3/h (air exchange rate = 4) is effected via the lower ventilation whole. Resulting in significantly lower exposure levels compared to the same air exchange rate via the upper ventilation hole. This can be explained with the consideration that DCM is heavier than air and accumulates in particular at the bottom of a room. Consequently it is more rapidly eliminated from the room via the lower ventilation hole and leads to lower exposure levels.

In order to investigate the influence of ventilation via the upper vs the lower ventilation hole, a second test series has been carried with 6 products under the same conditions as in test series 1 but with the ventilation via the lower ventilation hole.

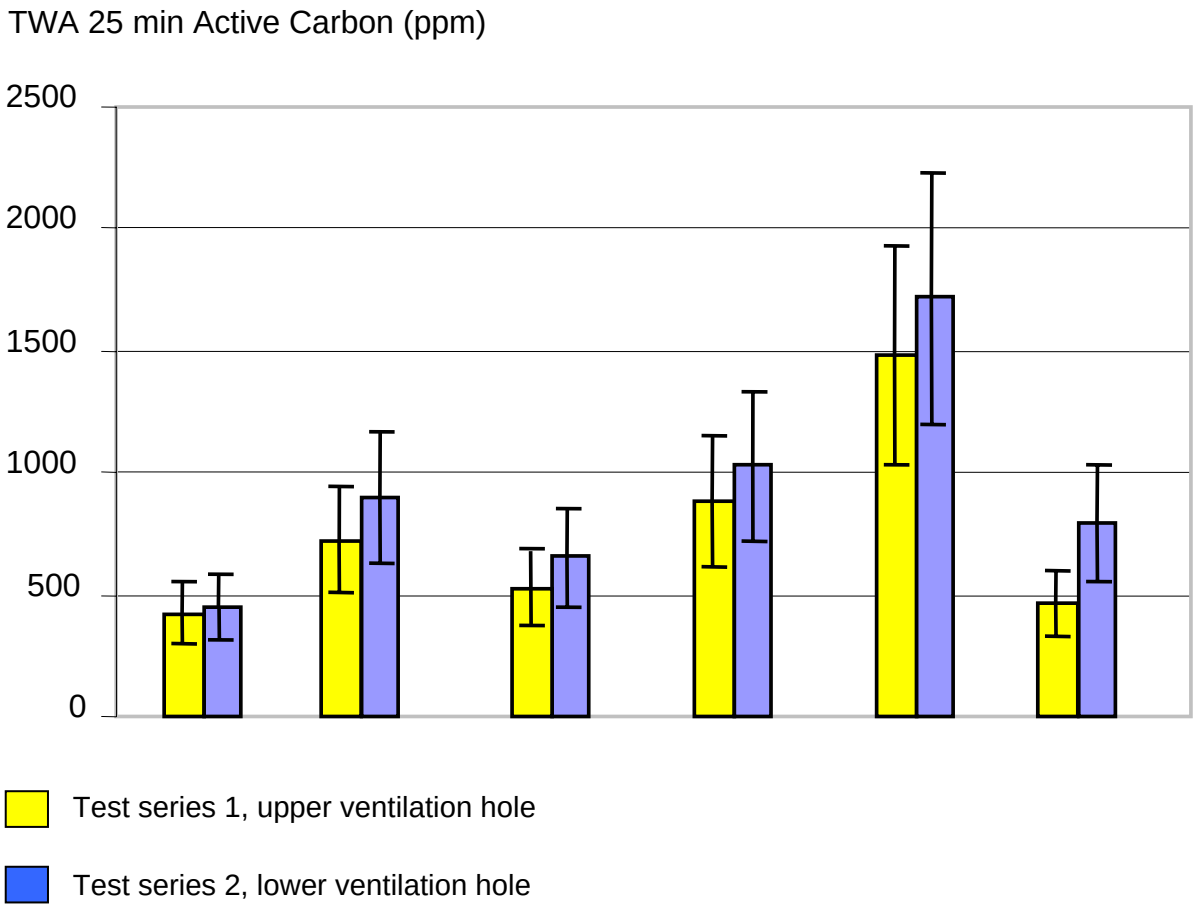


Figure 11: Effect of different ventilation conditions on DCM exposure (2)

The graph shows the results from test series 1 (in yellow) and 2 (in blue) for the identical products. Against the expectation according to the above explanation, all results for the identical products are slightly higher in test series 2. An interpretation of these results is difficult. A possible explanation might be that specific air fluid dynamics have occurred in this second test.

However, the overall conclusion from the variation of the ventilation conditions is that an increase of the air exchange rate is approximately inversely proportional to the exposure levels.

It is possible to extrapolate worst case scenarios on the basis of the test results. With an air exchange rate of 1 (corresponding to closed windows and doors in a small room of ~ 15 m^3, which is interpreted as a worst case scenario) and product amounts of 500 to 1000 ml (according to producer indications 1 litre paint remover is sufficient for 3 to 6 m^2 and thus usually sufficient for the stripping of a whole door on both sides corresponding to approximately 4 m^2) exposure levels are to be expected up to ~ 4.600 ppm (for 500 ml) and ~ 9.200 ppm (for 1000 ml).

The corresponding calculation for open doors and open windows (air exchange rate 10) results in exposure levels up to ~ 450 and 900 ppm for 500 ml and 1000 ml respectively.

Conclusion

An increase of the air exchange rate is approximately inversely proportional to the exposure levels and allows the extrapolation of the test results to different ventilation conditions.

4.4.8 Previously reported test results

Numerous exposure measurements have been carried out at workplaces due to several fatal accidents between 1990 and 2000. The results show the following occupational exposure levels due to the application of DCM containing paint removers.

	Amount of measurements	**Mean value***	**95 % percentile***	**Min**	**Max**
Paint stripping, indoor, > 0,5 m^2	60*	392	702	84	867
Paint stripping, indoor, small areas < 0,5 m^2 (restoration works)	6	65	104	29	111
Outdoor paint stripping	37**	150	382	45	650

Table 4-1: DCM Exposure levels (ml/m³, ppm) during paint stripping
* during 19 of 60 Measurements the measuring range was exceeded. therefore the statistical values are restricted to 41 measurements
** 24 measurements from the "Outdoor paint stripping" have been carried out by the company BASF. The results of these measurements can be found in more detail in the annex (see Table 11-2)
Source: [Rühl 2003b]

The Technical Rules for Hazardous Substances on "Substitute materials, substitute techniques and applications limitations for methylene chloride paint stripping agents" [TRGS 612 2002], refers to these data.

In the Annex details of further previously reported test results are documented under point 11.5.

In the U.K several measurements on exposure during paint stripping have been recently carried out. The test results show mean exposure levels during application, scratching, and hosing off ranging from 44 up to 203 ppm under different application conditions. Detailed test results can be found in the annex in Table 11-3, Table 11-4 and Table 11-5. Even if a direct comparison of these measurements with those summarised in Table 4-1 is difficult, the recent measurements that have been performed in the U.K. with effectively vapour retarded products may indicate that modern, good vapour retarded paint removers may result in lower exposure values compared to those that have been used in former test series (see e.g. Table 11-2). But this is controversially discussed and may also be due to unrealistic test conditions.

The overall conclusion from previously reported test results can be summarised as follows: Exposure values during outdoor use range from minimum values around 20 ppm to above 1000 ppm in some exceptions. Mean values range from far below 100 ppm up to 475 ppm.

In general, exposure values during indoor use range from far below 100 ppm to several thousand ppm. The crucial factor for exposure is ventilation. Good ventilation (either sufficient through ventilation or sufficient active ventilation) can result in exposure values well below 100 ppm (see e.g. Table 11-4 with mean exposure values ranging from 45 to 66). Insufficient ventilation or paint removing without ventilation leads to exposure values up to several thousand ppm (see Table 11-6)

5 DCM-effect assessment corresponding to the application of paint strippers

The recent study on behalf of the European Commission on “Methylene Chloride: Advantages and Drawbacks of Possible Market Restrictions in the EU” [Tukker et al 1999] contains a discussion on the risks of the exposure to DCM for humans and animals through the assessment of a dose-response relationship of the exposure level and toxicological effects. The study provides an overview on the different possible health effects. It does not represent a regular EU risk assessment.

DCM causes several adverse health effects due to a possible uptake via skin, the respiratory system and the intestinal system. During its application as paint stripper the primary contamination paths are via skin contact and respiration. The exposition to DCM may result in several acute and chronic toxic effects including adverse effects on the central nervous system, blood skin and other target organs (e.g. liver, occasionally kidneys). Examples for reported health effects include the following:

- Causes headaches, decreased attention span, disorientation and loss of consciousness after high exposures
- Metabolises to carbon monoxide which increases the risk of heart attack
- Causes irritation to eyes and skin and skin burns after prolonged exposure
- Laboratory studies indicate chronic exposure causes cancer

The principal objective of the present study is to determine application conditions that assure that no further fatal or severe accidents shall happen. Fatal accidents have occurred as a consequence of inhalation of DCM. Therefore, in the context of the present study, the acute inhalation effects of DCM are of special importance. Table 5-1 gives an overview on selected acute inhalation effects of DCM in relation to exposure levels. A recent compilation of exposure effects can be found at Tukker et al. 1999.

Exposure level in air [ppm]	Effect	Reference
180-710	CO-Hb-levels in blood 1.9 to 6.8%	IPCS 1996
100-300	Odour threshold for most persons	Hall et al 1990
	No neuro-behavioural effects were observed in human volunteers following exposure to 250 ppm for 7.5 hours	Hall et al 1990
300 to 800	At exposure times around 1 hr (at least 40 minutes) decreased performance in neuro-behavioural tests	Hall et al 1990
~ 700	Mild CNS effects in humans after exposure for 1.5 to 3 hours	Putz 1976
500 - 1000	Lightheadedness after 1 – 2 hour exposure	Hall et al 1990
~900	Dizziness occurs	INEOS
~ 1000	Exposure from 20 to 30 min to 1000 ppm caused lightheadedness;	INEOS
	Irritating to eyes; may cause conjunctivitis	(see Table 11-8)
~ 2000	symptoms of nausea, headache and vomiting may be experienced	INEOS
> 2000	Central nervous system significantly affected	INEOS
7200	Paresthesia, irritation	Hall et al 1990
>8000	Narcosis after 30 min to 4 hrs at exposure levels from 8000 to 20000 ppm	Hall et al 1990
	Continued exposure will lead to unconsciousness and can prove fatal;	VCI 1999
	Narcosis has been reported following exposure to 69000 mg/m^3 (~ 20000 ppm)	Tukker 1999
	Death has occurred when two persons fell into a with DCM; air samples showed concentrations of 538000 mg/m^3	Manno 1998

Table 5-1: Acute inhalation human health effects of methylene chloride in relation to exposure levels

With respect to acute inhalative effects for humans it can therefore be stated that continued exposure

- below 300 ppm CO-Hb levels start to increase slightly; neuro-behavioural effects are not reported
- above 300 ppm may cause minor effects on the central nervous system
- above 500 ppm lightheadedness
- above 1000 ppm eye irritation and dizziness
- above 2000 ppm may cause symptoms of nausea, headache and vomiting and the central nervous system may be significantly affected
- above 8000 ppm may lead to unconsciousness and to death

As an outcome of dose-response assessments NOAELs and LOAELs can be derived. DCM has mild CNS effects in humans as reported following exposure to concentrations as low as 694 mg/m^3 for 1.5 to 3 hours (Putz et al., 1976). This corresponds to a short term inhalative human LOAEL of approximately 200 ppm. The “Agency for Toxic Substances and Disease Registry” concluded a human LOAEL of 300 ppm for the acute inhalative toxicity of DCM [ATSDR 2000]. For further considerations the latter, more recently derived LOAEL for human inhalative toxicity of 300 ppm will be taken as a basis.

6 Integrated health effect appraisal

When discussing possible health effects related to paint stripping activities one should keep in mind that also all mechanical as well as all chemical paint removing activities are usually related to specific risks or are connected to severe disadvantages (time/costs). A comprising risk assessment can not be the scope of the present study. For an integrated health effect assessment it has to be relied on existing dose response assessments and exposure assessments.

Paint stripping is an activity which is carried out under varying conditions and by different user groups. For the prevention of health risks due the use of paint strippers during their application different user groups have to be taken into consideration.

Persons who are using paint strippers in an industrial or professional environment are usually working with higher quantities of paint strippers and are more frequently exposed. On the other hand consumers who are less frequently exposed also include particularly susceptible persons such as very young, elderly or infirm persons. As a consequence the corresponding risk has to be considered differently. Table 6-1 gives an overview on the relevant user groups and a characterisation of the corresponding risks with respect to the frequency and duration of exposure (short, medium and long term).

User group	Group characteristics	Risk characterisation
Industrial user	▪ frequent use ▪ big amounts of paint stripper ▪ closed use in installations according to VOC directive installations	risk of medium or long term exposure risk of accidents if work protection measures are disregarded
Professional user	▪ frequent use ▪ small to big amounts of paint stripper ▪ indoor and outdoor use ▪ open use	risk of repeated short term exposure and/or to medium and long term exposure
DIY user	▪ low frequency of use (e.g. up to several times per year) ▪ usually small amounts of paint stripper ▪ indoor and outdoor use ▪ open applications	risk of infrequent short term exposure possible exposure of particularly susceptible groups

Table 6-1: User groups of paint strippers and characterisation of typical risks.

6.1 Health effects from DCM containing paint removers

6.1.1 Occupational exposure limits to DCM

Based on existing risk assessments (see e.g. [IMM 1998] several countries have established different short and long term exposure limits for occupational exposure to DCM. At present neither a definitive nor an indicative European occupational exposure limit for DCM exists. Table 6-2 shows established occupational exposure limits in several countries.

Limit value air	Germany, Switzerland	U.K.	NL	Denmark Italy Portugal	Sweden	USA (OSHA)	Norway
8 hr TWA [mg/m^3]	360	350	350	174	120	82	125
8 hr TWA [ppm]	100	100	100	50	35	25	35
15 min STEL [mg/m^3]	1800	1050	1750		250	421	1750
15 min STEL [ppm]	500	300	500		70	125	500

Table 6-2: Established DCM air concentration exposure limits in several countries
8 hr TWA = eight hour time weighted average
15 min STEL = short term exposure limit for 15 minutes)

Established long term occupational exposure limits (8 hr TWA) within the EU Member states range from 35 to 100 ppm. Established short term exposure limits range from 70 to 500 ppm. Remarkable is a comparatively low limit value in the USA which is in particular related to the potential role of DCM as cancer-causing substance. For the risk assessment in the occupational area existing exposure limits can be correlated with exposure levels.

6.1.2 Exposure assessment to DCM in the occupational sector

Occupational exposure occurs during outdoor and indoor use. Already existing measurements and the laboratory tests performed for the present study demonstrate that exposure levels range from ~ 20 ppm up to several thousand ppm occur (see chapter 4 and Table 6-4). Exposure levels above the established STELs and 8hr TWAs (see Table 6-2) may lead to adverse health effects and are not acceptable.

6.1.3 Acceptable exposure to DCM for consumers

For consumers the usual risk assessment approach relies on No or Lowest Observed Adverse Effect Levels (NOAELs and LOAELs). According to the relevant EU technical guidance on risk assessment, a risk assessment is to be conducted by comparing the exposure level, the outcome of the exposure assessment, with the NOAEL, the outcome of the dose-response assessment. Where it is not possible to establish a NOAEL but a LOAEL can be derived, the latter is compared with the exposure level [TGD RA 2003]. As in the case of DCM a NOAEL has not yet been derived. The LOAEL has to be taken as a basis for the further risk assessment.

Usually for consumers higher margins of safety are set compared to those for workers. This shall consider the fact that consumer products also may affect particularly susceptible persons such as very young, elderly or infirm persons. In the case of DCM containing paint removers it can not be excluded that these susceptible groups are exposed to DCM.

The typical risk assessment procedure for consumers applies a margin of safety up to 10 for the consideration of intraspecies variation and an additional margin of safety of 2 to 10 for the use of LOAEL instead of NOAEL.

Based on the LOAEL of 300 ppm [ATSDR 2000] and taking into account the formal established margin of safety of 10 for the consideration of intraspecies variation and a margin of safety of 3 for the use of LOAEL instead of NOAEL, an acceptable level for acute exposure of 10 ppm results for consumers.

The above LOAEL of 300 ppm has been derived for humans, an exposure time of 3 to 4 hours. The effects observed are decreased critical flicker frequency and auditory vigilance which can be regarded as less serious (reversible) health effects.

6.1.4 Exposure assessment to DCM for consumers

As the test results show, exposure depends to a large degree on the ventilation conditions, the type of product used (vapour retarded or not) and on the amount of paint stripper applied.

Ventilation conditions can best be described with air exchange rates (room volume air exchange per hour). The following table gives an overview on reported air exchange rates and corresponding ventilation conditions:

Ventilation conditions	Air exchange rate	Reference
Windows and door closed	0 – 0.2	Enius 2003
Windows and door closed	0 – 0.4	Zenger et al 2003
Windows and door closed	0,0 to 0,5	Fraunhofer Institut*
Windows and door closed in 15m^3 room	1.0	RIVM, Netherlands
Single sided ventilation (window skipped)	0.5 – 2	Fraunhofer Institut*
Single sided ventilation (4 Windows skipped)	1.3 – 1.7	Zenger et al 2003
Single sided ventilation (half opened window)	5 bis 10	Fraunhofer Institut*
Single sided ventilation (window fully opened)	9 – 15	Fraunhofer Institut*
Through ventilation (opposite windows skipped)	4-10	Enius 2003
Through ventilation (four windows open, door open)	11	Zenger et al 2003
Through ventilation (open opposite windows)	~ 30	Fraunhofer Institut*

Table 6-3: Air exchange rates and corresponding ventilation conditions
* cited by [Rauch 2003]

Ventilation conditions for proper use during DIY application are through ventilation with open doors or windows at opposite sides of the room. As Table 6-3 shows, such ventilation conditions correspond to air exchange rates range from above 10 to approximately 30. The conditions simulated in the laboratory tests (air exchange rate = 4) are considered as realistic but unfavourable. A small room (~ 15 m^3) with doors and windows closed and an air exchange rate of 1 time per hour defines a realistic worst case ventilation situation.

On the basis of these considerations and the test results, it is possible to estimate exposure levels (for proper DIY use, for use under realistic unfavourable ventilation conditions [i.e. test conditions] and for realistic worst case conditions) with vapour retarded (vapour retardation rate > 95%) DCM containing paint removers for different product amounts.

Application conditions	Exposure level range [ppm]		amount [ml]	air ex-change rate per hour	Ventilation conditions
	from	to			
worst case estimation	1600	3200	350	1	windows and door closed
test results (measured)	400	800	350	4	insufficient through ventilation
proper DIY use	160	320	350	10	through ventilation
proper DIY use, good ventilation	21	43	350	30	good through ventilation
worst case estimation	2286	4571	500	1	windows and door closed
test results (extrapolated to 500 ml)	571	1143	500	4	insufficient through ventilation
proper DIY use	229	457	500	10	through ventilation
proper DIY use, good ventilation	76	152	500	30	good through ventilation
worst case estimation	4571	9143	1000	1	windows and door closed
test results (extrapolated to 1000 ml)	1143	2286	1000	4	insufficient through ventilation
proper DIY use	457	914	1000	10	through ventilation
proper DIY use, good ventilation	152	305	1000	30	good through ventilation

Table 6-4 Estimated exposure levels for indoor use

Table 6-4 shows that product amounts of 500 ml in proper DIY use are estimated to result in exposure levels ranging from 76 to 457 ppm. Under unfavourable conditions exposures up to approximately 1150 ppm are expected. Worst case estimations amount up to 4571 ppm.

Product amounts of 1000 ml in proper DIY use are estimated to result in exposure levels ranging from 61 to 914 ppm. Under unfavourable conditions exposures up to approximately 2300 ppm are expected. Worst case estimations amount up to 9143 ppm.

6.1.5 Risk characterisation for occupational use

Due to its acute inhalative toxicity DCM can cause adverse health effects and death following the inhalation of DCM. DCM is classified as possibly carcinogen substance (carc. cat. 3).There is limited evidence of a carcinogenic effect. The further considerations are limited to the acute inhalative effects of DCM.

As a consequence DCM containing products pose specific health risks. If they are used properly and taking advantage from appropriate technical equipment (e.g. for ventilation or protection of the respiratory system) they can be applied without acute adverse health effects. If they are applied under inappropriate conditions, severe adverse health effects and even death can occur.

Occupational exposure limits	Exposure levels
$TWA_{8\ hrs}$ 35 to 100 ppm $STEL_{15\ min}$ 70 to 500 ppm	~ 20 to several thousand

Table 6-5: Comparison of occupational exposure limits with exposure levels for the occupational sector

A comparison of the occupational exposure limits with measured and estimated exposure levels shows, that in many cases of occupational use the exposure is below established occupational limit values, in other cases the exposure exceeds the limit values.

To conclude, a risk related to the occupational use of DCM containing paint strippers cannot be ruled out and there is a need for risk reduction measures that ensure that all exposure levels are below established occupational exposure limits.

6.1.6 Risk characterisation for consumer use

The following table relates the upper range of the estimated exposure values for the use of 500 and 1000 ml to possible acute inhalative health effects.

Use conditions	amount [ml]	exposure up to [ppm]	possible adverse health effects
open use, indoor, proper ventilation	500	457	▪ slight increase in CO-Hb levels ▪ slight decrease in neuro-behavioural performance ▪ usually no risk for life
open use, indoor, unfavourable ventilation	500	1150	▪ increase in CO-Hb levels ▪ slight decrease in neuro-behavioural performance ▪ lightheadedness, dizziness , eye irritation ▪ usually no risk for life
open use, indoor, worst case ventilation	500	4571	▪ symptoms of nausea, headache, vomiting ▪ CNS may be significantly affected ▪ usually no risk for life
open use, indoor, proper ventilation	1000	914	▪ increase in CO-Hb levels ▪ slight decrease in neuro-behavioural performance ▪ lightheadedness, dizziness ▪ usually no risk for life
open use, indoor unfavourable ventilation	1000	2300	▪ increase in CO-Hb levels ▪ lightheadedness, dizziness ▪ symptoms of nausea, headache, vomiting ▪ CNS may be significantly affected ▪ usually no risk for life
open use, indoor worst case ventilation	1000	9143	▪ symptoms of nausea, headache, vomiting ▪ CNS may be significantly affected ▪ risk for unconsciousness and death

Table 6-6: Possible acute inhalative health effects related to specific use conditions

The table shows that during proper indoor use of half litre amounts of DCM containing paint removers, no relevant health effects are expected for users. However, under unfavourable conditions (exposure levels up to 1150 ppm may occur) health effects are possible. These effects are still moderate and reversible and a short term exposure will not pose a risk for severe health effects due to occasional use. Under worst case conditions exposure levels up to 4571 ppm are expected. Such levels cause acute adverse heath effects. Usually there is no risk for life.

During proper indoor use of a whole litre of DCM containing paint removers, exposure levels up to 900 ppm may occur and the table shows the possible related health effects. These effects are still moderate and reversible and a short term exposure will not pose a risk for severe health effects due to occasional use. During unfavourable use exposure levels up to approximately 2300 ppm may occur. Such exposure levels are still related to reversible health effects that usually do not result in risk for life. Worst case conditions result in exposure levels up to 9143 ppm where adverse health effects and even unconsciousness and death may occur.

A comparison of the DCM exposure levels with the acceptable exposures allows to assess the risks related to the use of DCM containing paint strippers.

Use conditions	Exposure assessment	Acceptable exposure[3]	Conclusion
open use (500 ml), indoor, proper to worst case ventilation	76 to 4571 ppm	10 ppm	Acceptable exposure in all cases exceeded Adverse health effects in high exposures possible; risk reduction measures required → risk reduction measures are required
open use(1000 ml), indoor, proper to worst case ventilation	152 to 9143 ppm	10 ppm	Acceptable exposure in all cases exceeded Adverse health effects and death in high exposures possible; risk reduction measures required → risk reduction measures are required

Table 6-7: Comparison of the DCM exposure levels with the acceptable exposures for the consumer

It becomes clear that (against the formal margins of safety) the acceptable exposure is always exceeded, adverse health effects and under worst case conditions even death cannot be ruled out. Risk reduction measures are definitely required on the one hand to minimise exposure levels, on the other hand to reduce exposure of susceptible groups such as very young, elderly or infirm persons (see also chapter 9.1).

[3] Formally established acceptable exposure taking into account precautionary safety margins and all susceptible population sub-groups (see chapter 6.1.3)

6.2 Health effects from DCM free paint removers

As mentioned above, both, DCM containing and DCM-free substitutes seem to be available for almost every paint removing task even though their use may sometimes be related to specific disadvantages. It is not the scope of the present study to assess the health risks from DCM-free products and to compare them to those related to DCM-containing products. However the principal arguments that are in discussion shall be brought up:

The replacement of DCM containing products with DCM-free products would eliminate the risks that are related to the DCM content of paint strippers. However, there remain open questions with respect to possible adverse effects related to DCM-free products. The most important arguments that are brought forward in this context are the following:

- Several DCM free products exhibit high flammability. The replacement of DCM containing products with DCM-free products would lead to accidents due to the flammability of the alternatives and as a consequence to increased numbers of fatalities.

- Several DCM free products contain solvents that are attractive for solvent abuse. The replacement of DCM containing products with DCM-free products would lead to adverse health effects and deaths as a consequence of increased solvent abuse.

- DCM free paint removers contain several dangerous substances (see chapter 3.4: NMP, acetone, iso-butanol, etc.). Adverse effects are possible due to the exposure to single components or the mixture of components of DCM free products.

In Austria and Sweden the use of DCM in paint removers is prohibited since the beginning of the 19ninetees. The experiences related to the use of alternatives and related safety risks have not been systematically evaluated in both countries. However no problems did emerge in these countries due to the use of DCM substitutes and there is not a real need seen for DCM containing paint removers.

The risks related to the use of DCM free paint removers are not yet exhaustively assessed and balanced against those resulting from the use of DCM containing products.

In Germany a first systematic approach has been taken in this respect. An internationally composed expert panel consisting of all relevant stakeholders (e.g. representatives of VCI, ECSA, producers of DCM containing paint removers, producers of DCM free paint removers, the German EPA and the German federal ministry of environment) has carried out an assessment of the health risks from alternative substances concludes that all substitute substances contained in DCM free paint strippers “lead to reduced exposure, and as a result reduced health risks are expected by comparison with methylene chloride” [TRGS 612 2003]. In the document related to alternative substances for paint stripping it is stated:

> "With regard to human toxicological impacts, the potential hazards of methylene chloride consist primarily in its narcotic effect and concomitant central nervous system depression when used in high concentrations, such as occur in use as a result of its high volatility, as well as suspected carcinogenic effects. Like methylene chloride, the methanol contained in many paint strippers has a boiling point below 65º C and high vapour pressure. In comparison all substitute substances of Table 1 (note: corresponding to Table 3-3 and Table 3-4 of the present report) display greatly reduced vapour pressure.
>
> It should however be borne in mind that in the case of the organic substitutes, inflammable or explosive air/vapour mixtures can arise as a result of the longer exposure times of up to 24 hours, and in extreme cases up to 48 hours, which are to some extent required. Allowance needs to be made for this on large areas by means of cover measures, and, especially when the flame point of the paint stripping agent is below 55º C, by providing adequate ventilation.
>
> When using alkali substances, because of the ensuing caustic or irritant effects, preventative measures must be taken, in the form of relevant personal protection, in particular the wearing of gloves (polychloroprene or nitrile rubber) and protective goggles. Excepting the above, there are no objections regarding toxicological impact against the use of these materials."

The TRGS 612 has been published by the German Federal Ministry for Employment and Social Affairs and is in Germany generally accepted by the relevant stakeholders. However, this conclusion is internationally controversially discussed.

It was not within the scope of the present project to assess the risks of alternative substances in paint removers. Table 6-8 shows selected substitutes and relevant substance specific information which is relevant for a risk assessment.

Substance	CAS-Nr.	Risk phrases[4]	Vapour pressure [hPa at 20 °C]	Occupational exposure limit (DE)[5]	typical content [%]	LOAEL[6]
Acetone	67-64-1	11, 36, 66, 67	233	340 ppm	10-25	237 ppm[7]
Tetrahydrofuran	109-99-9	11, 19, 36/37	200	43 ppm	> 5	100 ppm[8] (animal studies)
Iso-butanol	78-83-1	10, 37/38, 41, 67	11.7	90 ppm	> 5	100 ppm[9]
n-methyl-2-pyrrolidone (NMP)	872-50-4	36/38	0.32	23 ppm	5-20	no info for acute inhalative effects
di-basic-ester (DBE)[10]	1119-40-0	none	0.27	none	50-70	1600[11]
Corresponding data for DCM						
Dichloromethane	75-09-2	40	453	100 ppm	75-90	300 ppm

Table 6-8: Selected substances contained in DCM free paint strippers

The substances have been selected in a first approach taking into account criteria such as risk relevant properties (risk phrases), exposure relevant properties (vapour pressure) and typical content of these substitutes in DCM free paint removers. The selection may be taken as a basis (to be enlarged or shortened) for the risk assessment of alternative paint removers.

Table 6-8 already contains relevant information that is required to carry out a risk assessment based on exposure assessment, dose response assessment and a risk characterisation for these substances in DCM free paint removers. However there are still important uncertainties and considerable further data inquiry and information evaluation is required to carry out a consistent risk assessment on these substances in DCM free paint removers. This goes far beyond the scope of the present study.

[4] R 10 = Flammable; R11 = Highly flammable; R36 = Irritating to eyes; R36/38 = Irritating to eyes and skin; R37/38 = Irritating to respiratory system and skin; R40 = Limited evidence of a carcinogenic effect; R41 = Risk of serious damage to eyes; R66 = Repeated exposure may cause skin dryness or cracking; R67 = Vapours may cause drowsiness and dizziness;

[5] Occupational exposure limits as established in Germany

[6] LOAEL - lowest-observed-adverse-effect level; the information on LOAELs are derived from toxicological information from several sources; it is possible that other LOAELs or NOAELs are established elsewhere.

[7] Humans: exposure 4 hrs, inhalation, neurological effects [ATSDR 1994]

[8] Rabbits: exposure 4 hrs, inhalation, from 100 to 12000 ppm, acute toxicity depending on concentrations: reversible effects of ciliar activity of the tracheal epithelium (100 ppm) up to substantial morphologic effects of the nasal mucosa [Gestis Stoffdatenbank: www.hvbg.de/d/bia/fac/stoffdb/index.html].

[9] Human, acute inhalative effects, irritation of eyes, nose and throat, headache, lightheadedness occur above 100 ppm [Gestis Stoffdatenbank: www.hvbg.de/d/bia/fac/stoffdb/index.html]

[10] Information presented is related to dimethyl glutarate, a main component in commercial mixtures of di-basic esters

[11] Humans: acute inhalative effects (no specific information) occur above 5600 mg/m^3 (~ 1600 ppm) [Gestis Stoffdatenbank: www.hvbg.de/d/bia/fac/stoffdb/index.html]

Di-basic esters are not attributed to risk phrases. However there remain uncertainties related to possible health risks that should be evaluated. This can be seen from the fact that e.g. dimethyladipate (a di-basic ester used in paint removers, cas-no 627-93-0) is not classified in the Annex I of Directive 67/548/EEC but has dangerous properties according to other information sources[12].

In addition, it should be noted with respect to di-basic esters which are not attributed to risk phrases, that di-basic esters usually occur together with other dangerous substances (e.g. n-methyl-2-pyrrolidone) in common formulations of paint removers (see tables Table 3-5 to Table 3-9). As a consequence paint removers that are based on di-basic esters usually contain dangerous substances posing possible health risks that need to be evaluated.

If one specific DCM free paint stripper exists that poses no health risks, the question is not answered whether DCM free paint strippers as a whole are less dangerous compared to DCM containing strippers.

For a consistent risk assessment and the comparison of risks related to DCM containing versus DCM free products particular uncertainties are to be expected in the exposure assessment where exposure duration and pattern have to be taken into consideration against the background of different performance (More product to be applied? Different application procedure necessary?[13]) and properties (e.g. different stripping speed) of the paint removers. Another difficulty will be the consideration of different risk types such as the consideration of possible accidents due to the flammability of substitutes or the risk related to the supposed attractiveness for solvent abuse of several substitutes.

[12] In Germany dimethyladipate is “WGK 1” which means slightly water endangering; repeated or prolonged exposure leads to dimethyladipate leads to blurred vision [Bégin 1999]; In the Swiss toxic list dimethyladipate is attributed to category 4).

[13] In the application of DCM alternatives spraying is quite frequent. This has the consequence that another important risk factor besides the evaporation is the formation of aerosols.

7 Evaluation of fatal accidents

Table 11-12 in the Annex under point 11.8 gives an overview on the evaluation of the reported fatalities including the literature citations.

The following table shows the split between fatalities in the occupational and private sector:

User group	Fatalities	Note
occupational	**24**	**total number from 1960 to 2002**
	12	work at a open stripping tank under poor protection measures
	5	cleaning works inside of tanks or sub deck reservoirs and overfall basins without or with insufficient active ventilation
	2	overhead work
	2	work in well below ground level (1 case, 2 fatalities correlated to mixed solvent barrels)
	1	Work in basement
	1	Work in small badly ventilated room
	1	spilling of large amounts of liquid
Private	**6**	**total number from 1960 to 2002** always in combination with at least one of the following factors: bad ventilation, small room, basement room, closed window, absence of personal protection, leaning over the paint stripper, spilling of large amount

Table 7-1: Split between fatalities in the occupational and private sector

In total 24 fatalities during occupational use of DCM containing paint strippers or solvents and 6 fatalities during use of DCM containing paint strippers or solvents in the private sector have been reported in a 40 years period from 1960 to 2002.

The numbers of fatalities in literature reviews differ slightly because of double counting's, different interpretation of the circumstances or because literature citations could not be obtained. The reporting on fatalities is taken form a wide variety of information sources and it can not be taken as granted that literature reviews cover the absolute number of fatalities related to the use of DCM in paint strippers.

The total number of fatalities (30) identified in the present study corresponds with the number derived from a literature review performed in 2003 where also a total of 30 fatalities are reported [Rühl 2003b]. This overview contains some inconsistencies (2 non fatal accidents are reported as fatalities; one fatality reported was related to the use of DCM but not to paint stripping; some fatalities can not be attributed unambiguously). On the one hand some literature citations from this review could not be obtained, on the other hand the present study contains some further literature citations. Generally it is inherent to literature reviews on DCM related fatalities that further relevant accidents may not be included. Taking these differences into account it is possible that the total number of reported fatalities for the relevant time frame amounts up to 38. This number includes also fatalities that have occurred outside the EU.

U.K. industry has performed a literature review on fatalities in EU member States with only 16 fatalities since 1961. Out of the 30 fatalities identified in the present study 15 have occurred within EU Member States (DE 6, UK 4, IT 2, FR 2, ES 1, NL 1), 5 outside Europe (USA 10, Australia 2, Japan 1).

The present review concentrates on fatalities directly related to DCM in paint removers. The information sources usually do not provide information whether the products in use contained vapour retardants. However, since the use of vapour retardants is state of the art since several decades it can be assumed that probably all of the accidents have occurred although vapour retarded products have been used. The degree of vapour retardation of the corresponding products is not known.

1 Fatality has been reported for the time frame from 1960 to 1970, 3 from 1971 to 1980, 10 from 1981 to 1990, 10 from 1991 to 2000 and 5 since 2001 (1 fatality could not be attributed). The attribution is not always possible and is sometimes made according to the reporting year. The question whether the increased reporting since around 1980 is in fact due to an increased number of fatalities related to the use of DCM containing paint strippers can not be answered.

Out of the identified 30 fatalities 12 cases of acute fatal intoxication using DCM containing paint strippers in occupational use and 1 cases of fatal intoxication in private use have been reported around the world in the 10 years period from 1992–2002. 4 private fatalities and 3 private cases of non-lethal intoxication as well as 10 fatalities and 4 non-lethal intoxications in the occupational sector have been reported for the period from 1960–1990. 2 occupational fatalities and 1 non-lethal intoxication have been reported without stating the year of the accident.

Occupational users

For the occupational fatalities the major underlying cause has been work at a open stripping tank under poor personal protection conditions. 12 cases out of 24 (50%) occupational fatalities and 1 non-lethal intoxication have been the consequence of the above mentioned work.

The second most important working circumstances reported have been cleaning works with DCM containing solvents inside of tanks or subdeck reservoirs and overfall basins. These circumstances account for 5 (~20%) fatalities and 1 non-lethal intoxication.

The rest of cases is caused by work in basement (1 fatality) , wells below ground level (1 case with 2 fatalities correlated to mixed solvent barrels), small badly ventilated room (1 fatality), overhead work (2 fatalities) and spilling of large amounts of liquid (1 fatality). In a second case of non lethal intoxication in a basement room the additional effect of open flames (welding) aggravated the health impacts of the solvent.

Additional impact parameters:

- In most of the cases either none or insufficient protective respiratory equipment and protective clothing has been worn. In 12 cases there is explicit information that even a half mask has not been worn.
- In no case respiratory protection equipment with independent air supply has been worn.
- In some cases breathing masks and gloves have been found at the side of the victims or immerged in the tanks.
- In the fatalities related to cleaning works inside of tanks the opening hole has been on top of the tank in every case.
- In no case forced ventilation has been used

The circumstances that have lead to the fatalities allow the assumption that that established maximum exposure values have probably been far exceeded in all reported cases. Under appropriate working conditions (in particular exposure levels below occupational exposure limits to be established e.g. by means of forced ventilation or by wearing respiratory protection equipment with independent air supply) the accidents could have been avoided.

Private Sector

In the private sector the fatalities and non-lethal intoxications have occurred due to bad ventilation (small room, basement room and/or closed window). Usually the reports on fatalities in the private sector do not contain specifications on amounts used. There is no indication that fatalities have occurred when 1 litre or less has been used.

Additional impact parameters:

- lack of protective clothing and respiratory equipment; only in 1 victim the presence of a half mask with organic vapour cartridge has been reported, 3 victims definitively did not wear any protective equipment, in 4 cases information on protective equipment (mask) is missing.
- heating with open flame (kerosene stove)
- open containments apart from the one in use
- spilling of large amounts of solvent (e.g. 5 litre in basement room) or
- leaning over the paint stripper (cleaning of bathtub by 13 year old boy)

Health effects leading to fatalities or severe intoxication

The major reported health effect and acute causes for fatality has been the ARDS with fatal pulmonary and/or cerebral oedema or diffuse tissue congestion and haemorrhage as manifestation of a multi-organ system failure.

In one private case repeated myocardial infarction occurred in correlation to the repeated application of DCM containing paint stripper in a poorly ventilated basement room over a period of 2 to 3 hours.

In non-lethal cases most of the patients experienced headache, nausea, dizziness, coordination problems, shortness of breath and unconsciousness. In 1 case generalised seizures and arrhythmias have been reported. in a case of long-term exposure (strip tank operator) the patient experienced symptoms of a toxic delirium.

In the cases blood samples have been taken a significant rise of CO-Hb levels and or DCM blood levels have been reported.

In general it can be stated that two mechanism are responsible for the severe health effects of DCM.

- A reversible direct narcotic effect on the central nervous system
- A metabolic elevation of the CO-Hb level in the blood proportional to time and intensity of the DCM exposure.

The rapid onset narcotic effect predominates in acute poisoning at high exposure levels, which as a consequence is not associated with high CO-Hb levels [Goullé, Lacroix 1999].

The second effect occurs at lower levels. This has been studied by [Steward et al 1976] showing that already a short exposure to DCM (2 hours results in formation of CO-Hb that continues to increase for some hours before slowly returning to normal levels. The half life of the elevated CO-Hb levels is more than twice the one observed in CO intoxication (13 hours to 5 hours in a sedentary person) [Stephen, Buie 1986]. The presence of methanol further prolongs the period of CO-Hb elevation and the cardiovascular stress.

Use of the paint stripper for a period of 3 hours, according to the directions, can easily produce CO-Hb saturation of 5–10%. Poorer ventilation or exercise can increase this level. A cumulative effect has been observed, when exposure periods are less than 24 hours apart. [Langehenning et al 1979]. Because of the induced hypoxia persons with pre-existing cardiovascular diseases are at higher risk than healthy persons which may not show any symptoms even at high CO-Hb levels.

When open flames have been used the combined effect of DCM and open fire leads to a phosgene poisoning characterised by the late onset of symptoms.

Concentration measurements related to accidents

In the cases where measurements of the DCM concentration have been conducted in the follow up of the fatalities concentrations up to 420.000 ppm have been detected[14].

In this context measurements to differentiate areas of different exposure levels have been conducted (see Annex Table 11-9 to Table 11-11). They show a clear pattern of danger levels with by far the highest solvent levels some centimetres above the liquid surface in dipping tanks and far higher levels near to the soil on the bottom of tanks or wells.

Conclusions

The medical technical evaluation allows the following conclusions

- It can be assumed that the majority of accidents has occurred despite the use of vapour retarded products. The use of vapour retardants has started in the 1960ies and has fine tuned over the years. Nowadays the use of vapour retardants is state of the art and products available at the market are vapour retarded. There are significant differences of the efficiency of vapour retardation but there is no information available on the efficiency of vapour retardation of the products that where in use related to the fatalities.

[14] In one case the investigation team used reenactment air sampling to estimate the potential exposure with results about 1250 ppm. The used activated charcoal tubes where at the breakthrough, so that the actual concentration was higher. Furthermore other solvents where present in high concentrations. All other exposure levels related to lethal concentrations are usually far above 10000 ppm (see e.g. [Hall, Rumack 1990] and [Novak, Hain 1990])

- 83% of fatal accidents have occurred in a professional or industrial environment due to the disregard of legal provisions and simple safety measures for the protection of workers. No fatality has occurred during use in an industrial installation underlying the prescriptions of the VOC Directive
- 17% of fatal accidents have occurred in the DIY sector disregarding safety advices
- Most accidents have occurred due to improper handling, disregard of personal protection measures (e.g. respiratory air protection equipment with independent air supply or adequate ventilation)
- Some accidents have occurred due to the unintentional spill of the paint stripper

8 Risk reduction measures

The risk reduction measures have to be seen against the background of the outcomes from previous chapters. The main outcomes are the following:

- The market demands for paint removing activities are quite diverse and there is no general answer possible which product types (DCM-containing or DCM-free) are more appropriate to satisfy the demands in each single application. Market demands are quite divers in different EU markets. Both, DCM containing and DCM-free substitutes seem to be available for almost every paint removing task even though their use may be related to performance and/or health related disadvantages.

- The risks related to the use of DCM free paint removers are not yet exhaustively assessed and balanced against those resulting from the use of DCM containing products. The conclusion from an expert panel is that the direct health related disadvantages are more important for DCM containing paint removers compared to DCM free paint removers [TRGS 612 2002].

- Exposure levels for DCM containing paint removers:

  - Exposure values during the use of vapour retarded products range from ~ 20 to several 1000 ppm. In worst case scenarios exposures are calculated to amount up to ~ 9000 ppm (see Table 6-4)

  - A 95% vapour retardation rate decreases exposure levels by more than 50% compared to non-vapour retarded products.

  - Exposure levels are approximately proportional to the surface treated and the amount used

  - Exposure levels are approximately inversely proportional to the air exchange rate (exchange factor of the room volume per hour)

- Effects:

  - continued exposure below 300 ppm: CO-Hb levels start to increase slightly; neurobehavioural effects are not reported

  - continued exposure above 300 ppm may cause minor effects on the central nervous system

  - continued exposure above 900 ppm may cause dizziness, lightheadedness and eye irritation

  - continued exposure above 2000 ppm may cause symptoms of nausea, headache and vomiting and the central nervous system may be significantly affected
  - continued exposure above 8000 ppm may lead to unconsciousness and to death
- Fatal accidents
  - most fatal accidents occurred in a professional or industrial environment due to the disregard of legal provisions for the protection of workers
  - some fatal accidents occurred in the DIY sector
  - most accidents occurred due to improper handling
  - some accidents occurred due to bad ventilation
  - some accidents occurred due to the unintentional spill of the paint stripper
- The risk related to the use of DCM containing paints strippers has to be considered differently for the different user groups:
  - occupational use (industrial/professional)
  - consumer use (DIY)
- A comparison of occupational exposure limits (35 to 500 ppm) with measured and estimated exposure levels (~20 to several thousand ppm; worst case ~9000 ppm) allows the conclusion that a risk related to the occupational use of DCM containing paint strippers cannot be ruled out and there is a need for risk reduction measures ensuring that all exposure levels are below established occupational exposure limits.
- A comparison of the DCM exposure levels with the acceptable exposures makes clear that the acceptable exposure is nearly always exceeded, adverse health effects and under worst case conditions even death cannot be ruled out. Risk reduction measures are required.

The most important conclusions are that risk reduction measures are necessary for the professional and for the consumer use of DCM containing paint removers. In the following different possible options to reduce the risks are proposed. In chapter 9 a specific recommendation is given and a justification explains the background why the project team has chosen the corresponding recommendation.

8.1 Risk reduction measures for consumer use

8.1.1 Background

For the use of DCM containing paint removers in the DIY sector occupational exposure limits and legislation for personal protection do not apply. Therefore the products itself have to be safe in the sense that

- either exposure levels must be excluded which may cause severe adverse health effects (limit: exposure above 2000 ppm).
- or exposure levels must be excluded which may cause health effects (limit: exposure above 300 ppm)
- or exposure levels must be excluded which may cause health effects taking into account established margins of safety (limit: exposure above 10 ppm)

Suitable conditions for DIY users can not be controlled by law or enforcing authorities. Consequently other possibilities for risk reductions have to be identified. The following risk reduction measures are possible:

- ban of DCM in paint removers intended for consumer use
- prescription of product specific safety criteria (maximum weight loss 1.85%[15])
- prescription of safety warnings and recommendations on the product containment to advice the user on suitable use conditions.
- prescription of specific conditions for the marketing (e.g. determination of maximum volumes for containments sold to consumers[16] or containment characteristics against unintentional spill).
- prohibition of self service sales and mandatory professional instruction on application conditions and health risks before sale

[15] The vapour retardation rate in the current proposal for restrictions on the marketing and use of DCM-containing paint removers relates the evaporation loss to that of pure DCM. For practical reasons the project team proposes to set as quality criterion the weight loss in % independent from DCM. A weight loss of 1.85% corresponds to 95% vapour retardation rate compared to pure DCM. Therefore the proposed criterion is 1.85% weight loss. The weight loss has to be measured by a standardised test method. To this end the laboratory test method for measurement of % weight loss of DCM based paint removers (see Annex point 11.6) could be taken as a basis. This method has been established by U.K. formulators of DCM based paint removers. It has proven to bring reproducible and reliable results.

[16] Exposure levels are approximately proportional to the surface treated and the amount used. Consequently a possibility to limit maximum exposure in the DIY sector is to sell DCM containing paint strippers in containments of a certain maximum volume. Provided that the DIY user only uses 1 product containment at a time, he

The test results show unambiguously that efficient vapour retardation is appropriate to limit the exposure to DCM during open use of DCM containing paint removers. Consequently vapour retardation (or weight loss) is an appropriate risk reduction measure.

Some accidents have occurred due to unintentional spill of liquid paint removers. Consequently an appropriate risk reduction measure would be product containments for liquid paint removers that prevent unintentional spill of the whole product amount if the bin is tipped over. This is already realised in the U.K. where several liquid paint removers for consumers are contained in bins with a small neck. An appropriate criterion would be e.g. maximum spill 50% if the product containment is tipped for 90°. For practical reasons a cover cap can be used as containment for the brush application. This criterion only applies for liquid DCM paint removers.

As mentioned, a possible risk reduction measure would be to encourage users to carry out proper use and to further limit possible exposure by simple safety measures. This could be done by prescription of safety warnings and recommendations on the front of the product containments for the marketing of DCM containing paint removers encouraging that some important points shall be regarded in order to avoid risks for health and life. The following points are a proposal for corresponding safety warnings:

- "Where possible use outdoors and not in enclosed spaces such as wells, basins or enclosed balconies!" Several accidents have happened in enclosed spaces where an adequate ventilation is difficult and high exposure levels are almost inevitable

- "If outdoor use is not possible provide for through ventilation by opening all doors and windows (minimum 1 open door and 1 open window)!". As explained above, ventilation is a crucial factor to avoid high exposure levels

- "Do not treat more than 0.5 m^2 at a time!" The amount for the stripping of 1 m^2 is up to 350 ml. The recommendation to treat only 0.5 m^2 indoors would result in amounts up to 175 ml and consequently in exposure levels under proper use conditions from 11 to 160 ppm[17] and even under worst case conditions below 1600 ppm[18].

- "Do not work longer than 1 hour at a time!" Against the background that exposure values increase during working phases and decrease during non-working phases, this is an additional risk reduction measure to ensure that critical exposure levels are not exceeded.

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can only use a certain amount and also treat a certain surface area.

[17] Extrapolation of the test results under the following conditions:
- proper use, good ventilation (air exchange rate 30, 0.5 m^2, 175 ml, lower exposure level)
- proper use (air exchange rate 10, 0.5 m^2, 175 ml, upper exposure level)

[18] Extrapolation of the test results under worst case conditions (air exchange rate 1, 0.5 m^2, 175 ml, upper exposure level)

- "Do not work repeatedly over several days!" This safety requirements is in particular for persons that are susceptible for heart diseases. A cumulative effect has been observed with respect to CO-Hb levels, when exposure periods are less than 24 hours apart. Persons with pre-existing cardiovascular diseases are at higher risk than healthy persons which may not show any symptoms even at high CO-Hb levels.

- "Do not use in the presence of children, pregnant women, old people and people with cardiovascular diseases or other health problems". This warning shall reduce the risk of possible unacceptable exposure of particularly susceptible persons such as very young, elderly or infirm persons.

Another possible measure to reduce risks would be the "prohibition of self service sales and mandatory professional instruction on application conditions and health risks before sale". The idea behind this measure is to rise awareness at the consumer and to provide professional instructions to the consumer on appropriate application conditions. Furthermore qualified salespersons would be required not to sell several containments to one consumer at a time. In Germany self service sales of DCM containing paint removers is prohibited[19]. It is only allowed to sell it over the sales counter or from a closed cupboard. The experiences related to this procedure are not only positive. DCM containing paint strippers have disappeared from the big self service chains but they are still easily available from small regional stores and painters purchasing associations.

8.1.2 Risk reduction options for consumer use

Option 1

Measures: Total ban of DCM in paint removers intended for consumer use

Result: If ban is respected, exposure to DCM from paint removers will be zero

Problems: - Possible risks due to exposure to substitutes from DCM free paint removers

Use of DCM containing paint removers (e.g. provided by other sources such as professional users or from other non EU countries) can not be excluded (low probability)

[19] According to the "Chemikalienverbotsverordnung", § 4 it is prohibited to sell products via self service which are classified as Xn (harmful) and R40 (limited evidence of a carcinogenic effect)

Option 2

Measures: Limit marketing of DCM containing paint removers intended for consumer use with specific restrictions:

- maximum weight loss 1.85%
- maximum volume of product containments 500 ml
- product containments that prevent unintentional spill (maximum spill 50%)
- mandatory safety warnings and application conditions (as specified in chapter 8.1.1)
- prohibition of self service sales and mandatory instructions from qualified salesperson

Result: If the instructions for application (half m^2 at a time, ventilation rate 10 to 30[20], outdoor use preferable) is taken into account by the consumer due to the instructions by the qualified salesperson, expected exposure ranges from 11 up to 160 ppm.

Problem:
- Low exposure that would be desirable according to the formal established margins of safety (10 ppm) can only be obtained in few cases. However the expected exposure values are below health effect levels.
- With a certain (low) probability consumers can still disregard the instructions on ventilation and recommended maximum area. As a consequence, exposure as under unfavourable but realistic conditions (up to ~ 1150 ppm) and even under worst case conditions (up to ~ 4600 ppm) are not completely impossible. If so, there is usually no risk for life but a possible risk for life for susceptible persons can not be ruled out completely.
- Possibility to buy several product containments and possibility to apply bigger amounts which would result in higher exposure and higher risk can not be excluded (low probability).

Option 3

Measures: Identical with option 2 with two changes:

- maximum volume of product containments 1000 ml (instead of 500 ml)
- recommendation to organise the sales over the counter in combination with instructions from qualified salespersons

[20] Corresponding to open doors and windows; see also Table 6-3

Result: If the instructions for application is taken into account by the consumer due to the instructions by the qualified salesperson, expected exposure ranges from 11 up to 160 ppm.

Problem:
- Low exposure that would be desirable according to formal margins of safety (10 ppm) can only be obtained in few cases. However the expected exposure values are below health effect levels.
- With a certain probability consumers can still disregard the instructions on ventilation and recommended maximum area. As a consequence, exposure as under unfavourable but realistic conditions (up to ~ 2300 ppm) and under worst case conditions (up to ~ 9200 ppm) are not completely impossible. Under worst case conditions a risk for life has to be taken into consideration.
- Possibility to buy several product containments and to apply bigger amounts which would result in higher exposure and higher risk can not be excluded (low probability).

Option 4

Measures Limit marketing of DCM containing paint removers intended for consumer use with specific conditions as in option 3 except prohibition of self service sales and mandatory instructions from qualified salesperson. That means the consumer may also buy the product in self service markets but would be informed with the mandatory safety warnings and application conditions (as specified in chapter **Error! Reference source not found.**). It would be in the consumers' own responsibility to obey the information.

Result: If the instruction for application is taken into account by the consumer due to the mandatory safety warnings on product containments, expected exposure ranges from 11 up to 160 ppm.

Problem:
- Low exposure that would be desirable according to established margins of safety (3 to 15 ppm) can only be obtained in few cases. However the expected exposure values are below health effect levels.

- The decision on regard or disregard of suitable ventilation and recommended maximum area is completely in the consumer's own responsibility. With a certain (medium) probability consumers will still disregard the instructions. As a consequence, exposure as under unfavourable but realistic conditions (up to ~ 2300 ppm) and even under worst case conditions (up to ~ 9200 ppm) have to be taken in consideration. If suitable ventilation conditions and maximum area recommendations are completely disregarded, there is usually no risk for life but a possible risk for life for susceptible persons can not be ruled out completely.

- If the consumer disregards the application conditions he may intentionally buy several product containments (self service → medium probability) and apply bigger amounts which would result in higher exposure and higher risk can not be excluded.

Option 5

Measures No action

Result: Unacceptable high exposure values are possible; fatal accidents in single cases can not be excluded.

8.2 Risk reduction measures for occupational use (professional)

8.2.1 Background

Due to practical reasons, professional users can hardly work on an economic basis with the conditions as described for consumer use. The legislation for the protections on workers from the health risks related to the exposure to chemical agents has to be applied.

Professional users need larger quantities and larger surfaces have to be treated in reasonable time frames. Working periods and consequently exposure periods are larger than for DIY users.

As a consequence of the analyses carried through so far, exposure levels should be below the respective national exposure levels (see Table 6-2).

These values can be realised under realistic working conditions if

- appropriate personal protection equipment (e.g. respiratory air equipment with independent air supply) is used

or

- appropriate technical equipment (e.g. sufficient air ventilation equipment) is used that enables exposure values below national occupational exposure limits

If these conditions can be assured, no health problems are expected.

In cases where large surfaces are treated and consequently high amounts of paint strippers are applied it may be difficult to achieve acceptable exposure levels by means of ventilation equipment. However, even in these cases or when very strict occupational exposure limits have to be kept this is possible by means of respiratory air equipment with independent air supply. The prescription of the corresponding equipment at national level can be established by Member States taking into account national particularities such as individual occupational exposure limits.

In the professional use the following measures are possible to reduce or eliminate the risks related to the use of DCM containing paint strippers:

- ban of DCM in paint removers intended for occupational use (professional)
- prescription of product specific safety criteria (e.g. maximum weight loss 1.85%)
- prescription of safety warnings and recommendations on the product containment to advice the user on suitable use conditions.
- prescription of appropriate equipment for the application
- sales of DCM containing paint removers only to certified users

The safety warnings could correspond to those proposed for the consumer use for the use of amounts below 0.5 litre (see 8.1.1) with the additional remark that for the use of amounts above 0.5 litre the compliance with occupational exposure limits has to be assured by the application of appropriate equipment.

It is an open question how appropriate equipment for the application can be prescribed and enforced.

A possible solution would be to set up a restriction that is correlated to the sales of DCM containing paint strippers. This restriction would require from the buyer to prove that appropriate respiratory air protection equipment or appropriate air ventilation facilities are available for him (e.g. sales contract or leasing contract to be provided as evidence) and that he commits himself in a written declaration to use the equipment and to keep respective occupational exposure limits according to the national prescriptions. The seller of DCM containing paint stripper would have to store these documents and to provide them upon request to the competent authority. It still has to be discussed whether such a restriction could be part of Council Directive 76/769/EEC on marketing and use or whether a different legal background may be selected.

Another possibility would be to restrict the marketing of DCM containing paint strippers to a certification system related to the use of DCM containing paint removers. Only “certified users” or in other words those companies who participate in the certification system (which includes all necessary aspects that are required for the safe use of DCM containing paint strippers such as the use of appropriate technical equipment, specifically trained stuff, etc.) would be allowed to buy and use DCM containing paint strippers.

8.2.2 Risk reduction options for occupational use (professional)

Option 1

Measure: Total ban of DCM in paint removers intended for occupational use (professional)

Result: If ban is respected, occupational exposure to DCM from paint removers will be zero

Problem:
- Possible risks due to exposure to substitutes from DCM free paint removers
- Use of DCM containing paint removers (e.g. provided by other sources such as from other countries) can not be excluded (low probability)
- Certain technical requirements can not be fulfilled [see TRGS 612 2003]

Option 2

Measure: Limit marketing of DCM containing paint removers intended for professional use with the following specific conditions:

- maximum weight loss 1.85%
- mandatory safety warnings and application conditions (as specified in chapter 8.2.1)
- sales of DCM containing paint removers only to certified users[21]

Result: If only certified users will be allowed to use the DCM containing paint removers, the exposure values can be kept below each national occupational exposure limit by means of appropriate technical equipment.

Problem:
- Cost intensive to organise an appropriate certification system
- With a certain (very low) probability also certified users can still disregard appropriate application conditions (although this would be knowingly infringing existing rules and clearly constitute deliberate misuse and consequences for liability). If so, a remaining risk for the health of workers can not be excluded.

Option 3

Measure: Limit marketing of DCM containing paint removers intended for professional use with the following specific conditions:

- maximum weight loss 1.85%
- mandatory safety warnings and application conditions (as specified in chapter 8.2.1)
- prescription of appropriate equipment for the application

Result: If appropriate technical equipment will be applied, the exposure values can be kept below national occupational exposure limits. If personal protection equipment is applied exposure can be completely excluded.

Problem:
- Difficulties to enforce the use of appropriate technical equipment in practice
- With a certain (low) probability also users who agreed to use appropriate technical equipment can still disregard appropriate application conditions. If so, a remaining risk for the health of workers can not be excluded.

[21] the term "certified users" means companies who participate in a certification system which includes all necessary aspects that are required for the safe use of DCM containing paint strippers such as the use of appropriate technical equipment, specifically trained stuff, etc.

Option 4

Measure: No legal action, enforcement of existing legislation

Result: If existing legislation is respected, occupational exposure to DCM from paint removers will be below national occupational exposure limits (see Table 6-2). No health effects are expected.

Problem: As reality shows, fatal accidents have occurred in spite of existing limit values. This is due to the lack of enforcement of the existing legal requirements.

8.3 Risk reduction measures for occupational use (industrial)

8.3.1 Background

Industrial installations (see Annex section 11.8) are defined in the VOC Directive[22] as stationary technical units where one or more specific activities falling within the scope of the directive are carried out. The purpose of the Directive is to prevent or reduce 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 specific activities defined in the directive in so far as they are operated above specific solvent consumption thresholds.

Paint stripping with DCM containing products lies within the scope of the Directive within the activity "surface cleaning"[23] if solvent consumption lies above 1 tonne per year.

For the use of DCM containing paint removers in industrial installations the respective legislation for industrial installations and the legislation for the protection of workers from the health risks related to exposure to chemical agents has to be applied. Emissions from installations are regulated and occupational exposure limits have to be respected and kept by appropriate safety measures. As a consequence there is no rational for a product specific restriction in industrial use.

With the VOC Directive in place, open installations need to be closed in order to comply with the directive. As a consequence, exposure is expected to be well below the existing occupational exposure limits.

[22] COUNCIL DIRECTIVE 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations

[23] Surface cleaning according to Council Directive 1999/13/EC: "Any activity except dry cleaning using organic solvents to remove contamination from the surface of material including degreasing. A cleaning activity consisting of more than one step before or after any other activity shall be considered as one surface cleaning activity. This activity does not refer to the cleaning of the equipment but to the cleaning of the surface of products."

Suitable conditions for the use of DCM containing paint removers in industrial plants are already existing within Directive 1999/13 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations. Consequently it is not required to describe any further details here.

8.3.2 Risk reduction options for occupational use (industrial)

Option

Measure: No legal action, enforcement of existing legislation

Result: With the VOC directive in place exposure is expected to be well below the existing occupational exposure limits. If existing legislation is respected, occupational exposure to DCM due to the use of DCM containing paint removers is far below existing occupational exposure limits. No health effects are expected.

Problem: As reality shows, fatal accidents have occurred before the VOC directive was implemented in spite of existing limit values. This was due to difficulties to enforce the existing limit values properly in open industrial installations.

9 Conclusions and recommendations

Background to the conclusions are

- Reproducible laboratory tests for the simulation of different conditions of the application of DCM containing paint strippers
- Previously reported results on exposure levels
- Medical and technical assessment of reported fatalities
- Evaluation of material and data provided by stakeholders
- Comments from the Member States to the draft final report
- Article 95 of the EC treaty related to the approximation of laws

The conclusions have to be differentiated for the three groups “consumer use” (sometimes designated as “Do It Yourself“ or “DIY” use), “occupational use (professional)” and “occupational use (industrial)”.

Based on article 95 of the EC treaty the adoption of EU wide harmonised measures are proposed.

9.1 Recommendations for consumer use

The project team recommends to to choose option 2 from the described options in order to reduce the risks related to the use of DCM containing paint strippers intended for consumer use, i.e. to limit the marketing in the following way:

- maximum weight loss 1.85%[24]
- maximum volume of product containments 500 ml (option 2) [25]
- for liquid product containments that prevent unintentional spill (maximum spill 50%)
- mandatory safety warnings and application conditions (as specified in chapter 8.1.1)
- prohibition of self service sales and mandatory instructions from a qualified salesperson

[24] Possible basis for measurement method see Annex, section 11.7 “Laboratory test method for measurement of % weight loss of DCM based paint removers”

[25] according to producer indications for various paint removers 500 ml is sufficient for paint stripping works for

It has to be kept in mind that a restriction of the marketing for the DIY market to 500 ml containments may lead to significantly lower sales volumes and thus severely affect the DIY market of DCM containing paint removers (see chapter 3.2). However, in order to minimise risks, the project team proposes the restriction of the marketing to 500 ml containments as the probability that adverse health effects may occur is lower compared to a marketing of paint removers in bigger containments.

The project team considers the sale in combination with instructions from a qualified salesperson a useful risk reduction measure.

Justification

As outlined above, expected exposure ranges from 11 up to 160 ppm under these conditions if the instructions for application is taken into account by the consumer. This recommendation implies that exposure as desirable according to formally established risk assessment procedures (10 ppm) can only be achieved in few cases (e.g. outdoor use on small surfaces or indoor use on small surfaces with very good through ventilation). However, if the conditions specified above are kept the expected exposure values are below health effect levels. Having in mind that the hazards and risks related to substitutes are not adequately assessed this seems to be acceptable.

Exposures above this range should be avoided as far as possible. Therefore the project team considers it useful to minimise the risk of inappropriate use conditions as far as possible in a double approach by

1. product specific measures (restriction of weight loss, product amount and minimisation of unintentional spill)

2. measures that shall avoid inappropriate use (mandatory safety warnings, no self service, instructions for safe use by qualified salesperson)

The product specific measures are explained above and do not need further explanation.

Inappropriate use shall be avoided by a combination of mandatory safety warnings, prohibition of self service sales and additional instructions for safe use by qualified salespersons. This will rise consumers' awareness and information status and will further reduce risks by reducing the possibility for unintentional use under inappropriate conditions. The German experiences show that it is a possible way to exclude the sales of dangerous substances to a far degree from self service sales, even if it does not completely eliminate sales without instructions and any risk of possible misuse.

1.5 to 3 m^2 and thus usually sufficient for the stripping of a whole door on one side.

With a certain probability consumers can still disregard the instructions on ventilation and recommended maximum area. This probability is estimated to be low because the consumer has to disregard the safety warnings on the product containment and those from the qualified salesperson.

If a consumer will disregard all safety recommendations and will apply the whole amount under unfavourable but realistic conditions exposure values up to ~ 1150 ppm are expected which are related to possible reversible health effects (CNS effects, lightheadedness, dizziness, eye irritation). Under worst case conditions exposure up to ~ 4600 ppm would be possible. If so, the probability for severe or fatal accidents is very low. The probability that these worst case conditions occur is estimated to be very low against the background of the combination of risk reduction measures.

Finally, intentional misuse if a consumer buys several product containments and applies intentionally bigger amounts which may result in higher exposure and higher risks can not be excluded but can be kept low if the instructions for safe use are comprehensive and effective.

Against the background of the proposed risk reduction measures results a new judgment of the related risks:

- The margin of safety for the consideration of the LOAEL (3) is reduced to a safety factor 1 because no continuous exposure (less than 3 to 4 hours) due to risk reduction measures and no adverse effects can be expected, consequently the 300 ppm can be regarded as quasi-NOAEL[26] and consequently there is no margin of safety required with respect to this.

- For consumers the effect assessment usually uses a margin of safety of 10 for intraspecies differences. If for the paint stripping work children and pregnant women can be excluded by prominent safety warnings and/or instructions by qualified salespersons, a safety factor of 3 is considered to be sufficient to cover the remaining sensitive subpopulations (old people and people with health problems).

These considerations lead to an acceptable exposure limit of 100 ppm.

[26] The LOAEL of 300 ppm [ATSDR 2000] has been derived for humans, an exposure time of 3 to 4 hours. The effects observed are decreased critical flicker frequency and auditory vigilance which can be regarded as less serious (reversible) health effects. An alternative derivation of a NOAEL for Human Health for consumer paint stripping would be the following:

- Effects of DCM on humans have been observed for
- CO - Hemoglobin - at continued exposure increase starts below 300 ppm
- minor (reversible) effects on the central nervous system above 300 ppm

Dizziness, light headedness and eye irritation are starting at 900 ppm; in connection with acute effects of paint stripping work this may be considered as the beginning of an adverse effect (= LOAEL). Dizziness may be considered as a starting point of wrong behaviour which may lead to a fatal outcome of exposure towards DCM-vapour.
From the LOAEL of 900 ppm a NOAEL is derived by use of a safety factor 3 (because of mild and reversible

To conclude all the above measures contribute to minimise the health risk related to the use of DCM containing paint strippers but the risks cannot be totally excluded. The project team is aware of the fact that desirable exposure levels according to agreed risk assessment procedures are exceeded in several cases. However the project team has chosen this recommendation against the following background:

- The expected exposure levels are in a range (11 to 160 ppm) that does not cause health effects

- The risks related to the use of DCM free paint removers are not yet adequately assessed and balanced against those resulting from the use of DCM containing products (see chapter 6.2). The present state of knowledge does not justify a ban of DCM containing paint removers because it is possible that the overall risks related to alternatives may be equal or higher compared to those from DCM containing paint removers. A systematic evaluation of the risks is necessary to clarify this aspect.

- On the other hand the use of DCM containing paint removers is related to considerable risks and the project team considers that all proportionate measures should be taken to minimise the risks. This is why a recommendation has been chosen that enables a high degree of product safety (weight loss restriction, limited volume and prevention of unintentional spill) and a high degree of consumer instruction and awareness. This is increase awareness and responsibility at the consumer as much as possible. This shall be particularly ensured by the prohibition of self service sales and mandatory instructions from sales persons which goes beyond the approach to prescribe solely mandatory safety warnings on the product containment.

9.2 Recommendations for professional use

The project team recommends to choose option 3 from the above discussed options for occupational use in the professional area[27] in order to reduce the related risks. That means to limit the marketing in the following way:

- maximum weight loss 1.85%

- mandatory safety warnings (as specified in chapter 8.2.1) and instructions on safe application conditions

- prescription of appropriate equipment for the application (option 3)

effects); thus the NOAEL would be 300 ppm what is consistent with the above mentioned value.

[27] i.e. all applications in the occupational sector excluding those that are used in stationary installations according to VOC Directive

Justification

As outlined above, occupational exposure limits as established in the Member States can be realised under realistic working conditions e.g. by means of appropriate respiratory air equipment with independent air supply or by sufficient forced air ventilation. With independent air supply “zero exposure” is possible and with forced air ventilation an appropriate air exchange rate can be achieved that enables to reach exposure levels below existing occupational exposure limits. If these conditions can be assured, no health problems are expected.

Appropriate ventilation shall be supported by restricting DCM losses into the work place environment by the use of efficient vapour retardants characterized by maximum allowable weight losses.

Even very strict occupational exposure limits can be complied without problems by means of respiratory air equipment with independent air supply. The prescription of appropriate equipment at national level can be established at national level by respective Member States rules taking into account national particularities such as individual occupational exposure limits.

In order to keep exposure levels as low as possible the project team considers it useful to further minimise the risk of inacceptable exposure by a restriction of the weight loss. Further product specific measures such as a restriction of product amounts or prevention of unintentional spill are not useful in the professional sector because professional users need larger quantities and larger surfaces have to be treated in reasonable time frames.

Specific provisions for immersion baths are not required as the work at immersion baths has to be performed in a safe way by applying appropriate technical equipment.

The same applies for façade stripping works. Façade stripping usually concerns comparatively big surfaces. As test results show occupational exposure limits are frequently exceeded during façade stripping works. As a consequence, in those cases where occupational exposure limits are exceeded during façade stripping, appropriate technical equipment is required in order to assure exposure below occupational exposure limits.

In order to reduce the risk of inappropriate use mandatory safety warnings should be given on the product containments. This is to rise the awareness of workers when they are working with DCM containing paint removers.

In order to make sure that appropriate protection measures are taken it is suggested to establish a regulation stating that sales of DCM containing paint strippers intended for professional use in containments with a volume of more than 500 ml is only allowed if the use of appropriate equipment to assure exposure levels below the national established occupational exposure levels is guaranteed.

It is a complex question how the prescription to use appropriate equipment can be put into practice. A possible approach is briefly discussed in chapter 8.2.2.

To conclude all the above measures contribute to minimise the health risk related to the use of DCM containing paint strippers but the risks cannot be totally excluded. The expected exposure levels are conform to existing occupational exposure limits. It seems to be crucial to find efficient ways to implement the use of appropriate equipment. Thus the risk for exposure scenarios with exposure values that may cause adverse health effects can be minimised or avoided.

A ban of DCM containing paint removers is not justified because the proposed risk reduction measures – if implemented – are appropriate to minimise or avoid the relevant risks.

9.3 Industrial users:

Paint removers in industrial installations that are covered by Directive 1999/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (VOC-Directive) are used in closed systems. Consequently there is no need to use vapour retarded products.

For the use of DCM containing paint strippers in industrial installations covered by the VOC-Directive there is no need for further regulation within the framework of Directive 76/769/EEC.

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11 Annex

The Annex provides relevant information and information that is relevant for the understanding and transparency of the report. The Annex of the final report will additionally include a compilation of material that has been provided by stakeholders.

11.1 Frequently used abbreviations

CO-Hb	Methaemoglobin (carbon monoxide bound to haemoglobin)
CNS	Central nervous system
DCM	Dichloromethane
DIY	Do it yourself
IR	Infrared
LOAEL	Lowest-Observed-Adverse-Effect Level
NOAEL	No-Observed-Adverse-Effect Level
ppm	parts per million
STEL	Short term exposure limit
TWA	Time Weighted Average
TWA 25 min	Time Weighted Average over 25 minutes
VOC	Volatile Organic Compounds

11.2 Products provided for laboratory tests

	Product name	Brand		Country
1	Dekapan	Akzo Nobel	fluid	BE
2	Blackfriars paint and varnish remover	Blackfriars	paste	UK
3	SuperDecap	Bricobi	fluid	BE
4	All purpose paint and varnish remover	Langlow	fluid	UK
5	Paint and varnish remover	Nitromors	fluid	UK
6	Super Afbijtmiddel/Super Decapant	Polyfilla	fluid	BE
7	Strypit paint and varnish stripper	Rustin's	fluid	UK
8	Controx B 39 / Muster 2 A (Handelsprodukt)	Kluthe 2	paste	DE
9	Controx B 39 / Muster 1 A	Kluthe 3	paste	DE
10	Controx B 39 / Muster 3 A	Kluthe 1	paste	DE
11	Controx B 39 / Muster 4 A	Kluthe	paste	DE
12	Controx B 39 / Muster 1 B	Kluthe	paste	DE
13	Controx B 39 / Muster 2 B	Kluthe	paste	DE
14	Controx B 39 / Muster 3 B	Kluthe	paste	DE
15	Controx B 39 / Muster 4 B	Kluthe	paste	DE
16	NB 410	Strippers	fluid	DE
17	NB 510	Strippers	fluid	DE

Table 11-1 Selected DCM containing paint stripping products that have been sent for laboratory tests

11.3 Laboratory test design and test programme

- Test room volume: 2.5 x 2.5 x 2.4 m = 15 m^3
- Ventilation installation: at opposite sides of the room 0.25 m2 openings will be used for defined ventilation. Lower edge of the upper opening 1.5 m above ground. The lower edge of lower opening on the opposite side 10 cm above ground. The following view illustrates the arrangement of ventilation holes:

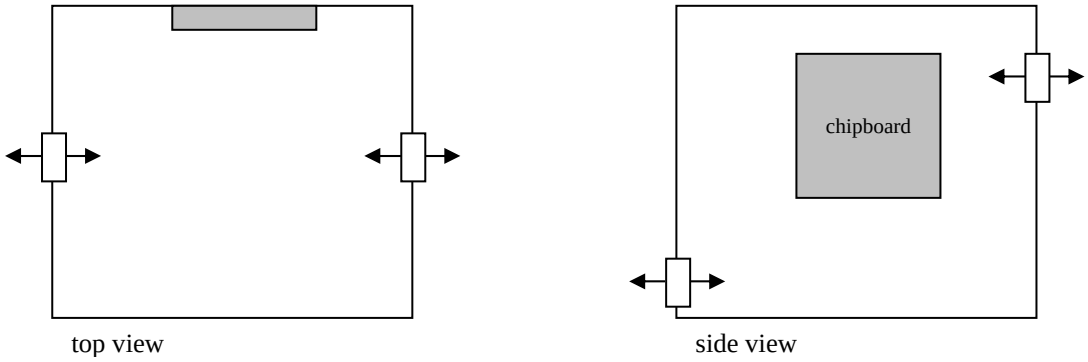

Figure 12: Arrangement of ventilation openings

- Ventilation: defined air volume exchange via the ventilation holes. Ventilation in separate trials in both directions (i.e. suction stream at the upper ventilation hole vs suction stream at the lower ventilation hole).
- Ventilation volume: air volume exchange in an average room of 15 m3 = 60 m3/h (standard ventilation condition).
- Test surfaces: 1 m2 chipboard (standard surface area)
- Defined amounts of paint stripper applied (350 ml)
- Temperature 17 to 20°C (monitoring during tests)
- Air humidity 40 to 65% relative humidity (monitoring during tests)
    - Different paint strippers have been applied under defined conditions
    - procedure and time for painting (5 minutes as standard application time)
    - defined time to effect on the work piece (10 minutes as standard effecting time)
    - defined procedure and time for scratching and removal (10 minutes as standard removal time)

- Monitoring of DCM concentration in air:
  - During the whole application time (painting, effective time, removal) a monitor collects the air on a DCM active carbon test tube (precision of measurements up to ±30%). The monitor is arranged at a distance of approximately 80 cm sideways to the centre of the chipboard (see Figure 3). The result will be the average DCM concentration in air during the whole procedure.
  - At the same time an IR sensor (Miran 1A) registers continuously the concentration of DCM in the air (precision of measurements: ±25%, in praxis approximately ±15%). The IR sensor is installed at face level in the centre and defined distance (length of arm; ~ 80 cm) to the chipboard (see Figure 3).

  The continuous measurement enables to compare the effectiveness of different vapour retarded paint removers during the application phase, the effecting time and the scratch-off phase.

The following picture illustrates the arrangement of the test equipment:

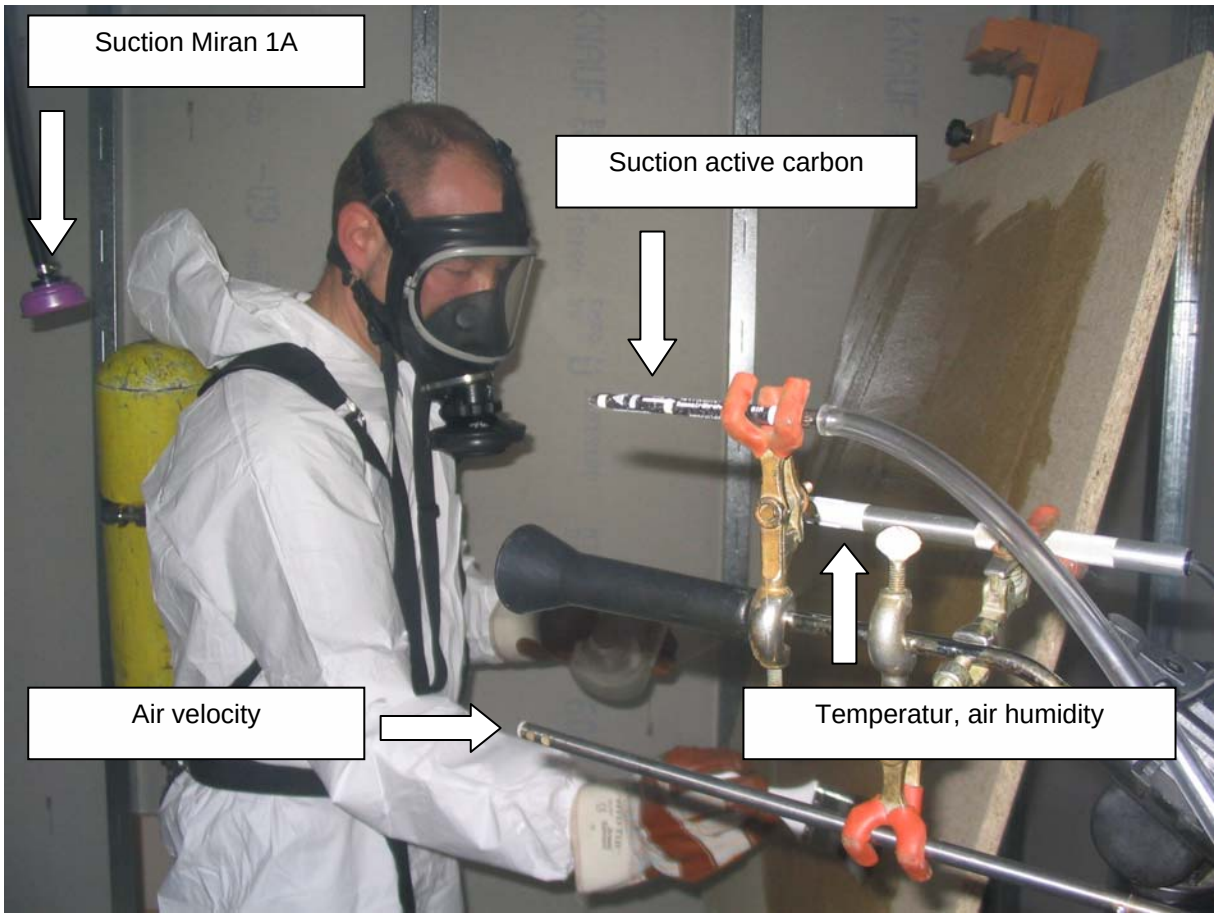

Figure 13: Arrangement of monitoring equipment

- Variations
  - VX01 and VP02 to VP09: 10 different products applied to upright plate boards at defined standard conditions (application procedure, ventilation, time, surface area, paint remover amount) in order to compare different products
  - VP09, VT03 and VT04: 3 different time combinations (for application time, resting time, scratch-off time) with one product in order to show the influence of time variation

Variation	application [min]	effecting [min]	removal [min]
Standard	5	10	10
Variation 3	2,5	20	3,25
Variation 4	5	5	5

  - VX01 and VH02: 1 application to a horizontal chipboard at defined usual time combination in order to compare application to upright and horizontal boards
  - VX01 and VR02: 1 application to a painted chipboard (usual alkyd resin) at defined usual time combination in order to compare application to upright and horizontal boards
  - VX01, VA02 and VA03 applications to varying surface areas
    - standard: 1.00 m²
    - variation 2: 0.25 m²
    - variation 3: 0.50 m²
  - VP02, VV03 to VV04: 3 variations of ventilations
    - standard: 60 m³/h (suction via upper ventilation hole)
    - variation 3: 90 m³/h (suction via upper ventilation hole)
    - variation 4: 60 m³/h (suction via lower ventilation hole)

Test programme

Standard conditions are:

- ventilation 60 m³/h via upper ventilation hole
- test surface and material 1m² non painted chipboard, upright position
- amount of paint remover applied 350 ml
- time for application/effecting/removal = 5/10/10 minutes

Variation of standard conditions:

Variation	No	date	Variation of standard conditions
VX01	1	9.10.	Product 1, standard conditions
VT03	3	9.10.	Product 1, (time variation: 2,5/20/3,25)
VT04	4	9.10.	Product 1, (time variation: 5/5/5)
VR02	6	9.10.	Product 1, painted chipboard
VV03	8	9.10.	Product 1; ventilation 86.6 m³/h (suction lower ventilation hole)
VV04	9	9.10.	Product 1; ventilation 57.6 m³/h (suction upper ventilation hole)
VP02	10	10.10.	Product 2, standard conditions
VP03	11	10.10.	Product 3, standard conditions
VP04	12	10.10.	Product 4, standard conditions
VP05	13	10.10.	Product 5, standard conditions
VP06	14	10.10.	Product 6, standard conditions
VP07	15	10.10.	Product 7, standard conditions
VP08	16	10.10.	Product 8, standard conditions
VP09	17	10.10.	Product 9, standard conditions
VA02	19	10.10.	Product 1; surface area 0,25 m², (87,5 ml; time adjustment 1.25/10/2.5)
VA03	20	10.10.	Product 1; surface area 0,5 m², (175 ml; time adjustment 2.5/10/5)
VH02	21	10.10.	Product 1, horizontal chipboard

These variations have been carried out on two days (9 and 10 of October 2003).

A second test series has been carried out for 6 products on 3 of November with the same arrangements under standard conditions but the following exceptions:

- DCM monitoring only via active carbon (no IR monitoring)
- ventilation 60m^3 via the lower ventilation hole

11.4 Documentation of test results

The documentation of the test results including the test results as excel file, individual test documents for the single measurements and pictures and videos taken during the measurements will be send as electronic version on CD-ROM.

11.5 Previously reported test results

11.5.1 BASF Measurements

Measurements performed by BASF in 1997 at outdoor paint stripping works at a housing estate (part 1) and a Danube barrage (part 2) [reference stakeholder involvement 20.09.2002]

Description/Source/Note	ppm mg/m^3	measurement time [minutes]	mean	min	max
BASF 1997, part 1, housing estate Paint Stripper: Settaquick, Fa VFG GmbH Hilden, 96% DCM	ppm				
Sample number 1; stationary		115	452		
Sample number 2; stationary		115	240		
Sample number 3, personal		115	198		
Sample number 4; stationary		110	186		
Sample number 5; stationary		110	452		
Sample number 6; personal; application 4 to 5 times		110	424		
Sample number 7; application		3	400		
Sample number 7; application		3	600		
Sample number 7; application		3	300		
Sample number 7; application		3	350		
Sample number 7; application		3	500		
Sample number 7; scratch off		3	150		
Sample number 7; application		3	400		
Sample number 7; application		3	400		
Sample number 7; application		3	800		
Sample number 7; application		3	850		
Sample number 7; scratch off		3	150		
BASF 1997, part 2, Danube barrage Paint Stripper: Abbeizer mit der Krähe, Fa Hohmann, 93% DCM	ppm				
Sample number 23, obere Kante; stationary		295	222		
Sample number 24, untere Bearbeitungsbühne; stationary		200	108		
1; personal		115	169		
2; personal		115	528		

Description/Source/Note	ppm mg/m^3	measurement time [minutes]	mean	min	max
3; personal		115	1222		
4; personal		115	389		
5; personal		115	217		
8; personal		115	306		
6; personal		115	694		
7; personal		115	500		
9; personal		120	389		
10; personal		120	500		
11; personal		120	472		
12; personal		120	164		
13; personal		120	267		
14; personal		120	219		
15; personal		120	417		
16; personal		120	158		
17; personal		120	556		
18; personal		120	278		
19; personal		120	181		
20; personal		120	528		
21; personal		120	361		
22; personal		120	244		
1, short time, Wehrschild, 7:35 – 09:30		3	100		
2 short time, Wehrschild, 7:35 – 09:30		3	300		
3 short time, Wehrschild, 7:35 – 09:30		3	300		
4 short time, Wehrschild, 7:35 – 09:30		3	200		
5 short time, Wehrschild, 7:35 – 09:30		3	500		
6 short time, Wehrschild, 7:35 – 09:30		3	300		
7 short time, Wehrschild, 7:35 – 09:30		3	300		
8 short time, Wehrschild, 7:35 – 09:30		3	350		
1 short time, Wehrschild, 10:00-12:00		3	300		
2 short time, Wehrschild, 10:00-12:00		3	500		
3 short time, Wehrschild, 10:00-12:00		3	450		
4 short time, Wehrschild, 10:00-12:00		3	750		
1 short time, Wehrschild, 13:00-15:00		3	600		
2 short time, Wehrschild, 13:00-15:00		3	550		
3 short time, Wehrschild, 13:00-15:00		3	1500		
4 short time, Wehrschild, 13:00-15:00		3	600		
5 short time, Wehrschild, 13:00-15:00		3	700		
6 short time, Wehrschild, 13:00-15:00		3	1900		
1 short time, Wehrschild, 7:30-9:30		3	300		
2 short time, Wehrschild, 7:30-9:30		3	300		

Description/Source/Note	ppm mg/m^3	measurement time [minutes]	mean	min	max
3 short time, Wehrschild, 7:30-9:30		3	300		
4 short time, Wehrschild, 7:30-9:30		3	300		
1 short time, Wehrschild, 10:00-12:00		3	250		
2 short time, Wehrschild, 10:00-12:00		3	300		
3 short time, Wehrschild, 10:00-12:00		3	300		
4 short time, Wehrschild, 10:00-12:00		3	250		
5 short time, Wehrschild, 10:00-12:00		3	350		

Table 11-2: DCM exposure levels [ppm] during outdoor paint stripping works at a housing estate (part 1) and a Danube barrage (part 2)

11.5.2 UK Industry and U.K. local authority measurements

Methylene Chloride Paint stripping Monitoring Data (Reference: stakeholder opinions 2002/2/28)

Several case studies; monitoring of DCM concentration

Description/Source/Note	ppm mg/m^3	number of values	mean	min	max
Case study 1: paint stripping of an article; double doors two meters from the work piece	mg/m^3				
1 m down wind; application			247		459
1 m up wind; application			35		
Head height operator; application			247		
Head height operator; scrapping off			**707**		
1 m down wind; scrapping off			177		1413
wood surface after stripping off			530		
Case study 2: On site paint stripping at a block of flats; tented sheeting used for protect work in progress; personal monitoring tubes, 3 static positions	mg/m^3				
Inside tent, static position 1			106		
Inside tent, static position 2			226		
Inside tent, static position 3			**357**		
Outside tent; worn by supervisor			21		
Inside tent, worn by 1st operator			208		
Inside tent, worn by 2nd operator			318		
Case study 3: paint stripping of 2nd and 3rd Floor stairway walls of a 6 floor building; Two local exhaust ventilation machines	mg/m^3				
operator personal breathing zone during application (brush on the wall and stripping = scrape off)			86		
static during stripping			58		
static, whole process			80		
static background, 6th floor during final 50 minutes			8		
Case study 4: stripping of textured coating from a ceiling; brush application 28 minutes; stripping 11 minutes; Three stage airlock at the door; all windows sheeted; one extractor unit machine for ventilation Personal monitoring operator during application and stripping	mg/m^3		**710**		

Table 11-3: Results from several case studies; monitoring of DCM concentration[mg/m^3]

INEOS Chlor ltd: Methylene Chloride Paint stripping atmospheric monitoring; indoor use; atmospheric monitoring case study using popular UK commercial paint stripping product [Reference: opinions 2002/2/16].

Description/Source/Note	ppm mg/m^3	number of values	mean	min	max
UK commercial paint stripping product ventilation: door, window, 4.3x3.7x2.9 m room; 600 ml of paint stripper poured into a beaker and painted onto the door being stripped; 5 minutes later same procedure with another 400 ml Scrapping off same procedure after 45 minutes with 500 ml					
throughout stripping at substrate (15 cm to door)	ppm			20	350
	mg/m^3			70	1240
throughout stripping in the rest of the room	ppm			20	80
	mg/m^3			70	280
personal exposure 1: tubes worn over 5 hour working period which included 1.5 to 2 h working period and quoted as 8 h TWA	ppm		53		
	mg/m^3		187		
personal exposure 1: tubes worn over 5 hour working period which included 1.5 to 2 h working period and quoted as 8 h TWA	ppm		64		
	mg/m^3		226		
results from further series of similar measurements; personal exposure	ppm		45-66		550
	mg/m^3		160-230		1940
no ventilation	ppm		to high		

Table 11-4: Results from methylene Chloride Paint stripping atmospheric monitoring; indoor use

INEOS Chlor ltd: Methylene Chloride Paint stripping atmospheric monitoring; atmospheric monitoring case study during professional paint removing from an external façade (measurement April 2004)

- typical U.K. Methylene chloride based, vapour retarded products:
  25 l (1.5 per m²) of Product 1: paint remover, 82% DCM, Evaporation rate 1.05%
  37 l (2.2 per m²) of Product 2: pigment residue remover, 53% DCM, Evaporation rate 0.43%
- Measurement: portable IR-detector (data logging all 70 seconds indicating an average value for the past 70 seconds; sampling head held in the breathing zone of the operator)
- Additional measurement: 2 passive adsorption monitors worn and exposed during the entire working period including breaks giving time weighted average values
- Periodic measurement of wind velocity, air temperature and relative humidity:
  dry, warm, sunny, calm wind
- external brick wall painted with 2 coats of styrene-acrylic based paint

- Section A: unsheathed
- Section B: sheeted
- Application: brushing, decanting from a ~ 15 l containment into working bucket ~ 2 l for application
- Stripping: hosing with high pressure hot water (80°C)
  Scratching off at a small area of Section A

Description/Source/Note: INEOS Chlor, external facade, April 2003	ppm mg/m^3	number of values	mean	min	max
paint removal section A unsheathed					
application Product 1 (brushing) 22 minutes	ppm		122*	0	~400
	mg/m^3				
effection time ~ 15 minutes	ppm			0	~10
	mg/m^3				
removal time ~ 13 minutes scraping	ppm		44*	0	~105
	mg/m^3				
removal time ~ 56 minutes hosing	ppm		49*	0	~100
	mg/m^3				
application product 2 ~20 minutes	ppm		73*		~130
	mg/m^3				
effection ~ 30 minutes	ppm				
	mg/m^3				
removal ~ 110 minutes hosing	ppm		20*		
	mg/m^3				
Personal Monitor Operator TWA	ppm		34		
Personal Monitor Assistant TWA	ppm		7		
Personal Monitor Analyst 1 TWA	ppm		8		
Personal Monitor Analyst 2 TWA	ppm		5		
paint removal section B sheeted					
application Product 1 (brushing) 17 minutes	ppm		181*		~510
	mg/m^3				
effection time ~ 29 minutes	ppm				~45
	mg/m^3				
removal time 5 minutes + 5 minutes resting vacuum hot water wash device	ppm		101*		~250
	mg/m^3				
removal time 16 minutes hosing	ppm				~330
	mg/m^3				
removal time 15 minutes scraping	ppm		169*		~280
	mg/m^3				
resting time 59 minutes	ppm				~20
	mg/m^3				
application P2 19 minutes brushing	ppm		64*		~110
	mg/m^3				
effection P2 31 minutes brushing	ppm				
	mg/m^3				
removal P2 26 minutes hosing	ppm		121*		~240
	mg/m^3				
Personal Monitor Operator TWA	ppm		31		
Personal Monitor Assistant TWA	ppm		5		
Personal Monitor Analyst 1 TWA	ppm		22		
Personal Monitor Analyst 2 TWA	ppm		14		

Table 11-5: Results from methylene chloride paint stripping atmospheric monitoring; atmospheric monitoring case study during professional paint removing from an external façade
* 15 min TWA

11.5.3 Other reported test results

Tukker and Simons report several exposure levels (reference: Tukker 1999) for consumer and professional use.

Description/Source/Note	ppm mg/m^3	number of values	mean	min	max
US EPA 1990 Exposure estimations most values below 1770	mg/m^3			35	14110
ICI (solvent producer) small room with through ventilation TWA = 2 h time weighted average	mg/m^3		289		3530
ICI (solvent producer) small room with through ventilation during application; 2-h-TWA	mg/m^3		460		
ICI (solvent producer) small room with through ventilation during scrap of; 2-h-TWA	mg/m^3			710	1410
ICI (solvent producer) small room without ventilation 2-h-TWA	mg/m^3				14000
ICI (solvent producer) good ventilation 8-h-TWA	mg/m^3		187 to 226		
HSE UK DCM exposure assessment 1998 unventilated room; 1-h-TWA	mg/m^3		840 to 2765		
HSE UK DCM exposure assessment 1998 room with door open; 1-h-TWA	mg/m^3		130 to 948		
Sloof and Ros 1988 referring to Otson et al 1981 unventilated room; 8-h-TWA	mg/m^3		460 to 2980		
Sloof and Ros 1988 referring to Otson et al 1981 ventilated room; 8-h-TWA	mg/m^3		60 to 400		

Table 11-6: Several reported DCM exposure levels [mg/m^3] for consumer and professional use

11.6 Health effects

Hall et al 1990 made a compilation of health effect. The following Table 11-7 shows acute effects and potential airborne concentrations:

Effect	Concentration [ppm]	Exposure duration
Odor threshold	100 – 300	On exposure
No acute effects	100 - 280	Up to 7.5 hrs
Altered responses on sensory and psychomotor tests	300 - 800	at least 40 min
Lightheadedness	500 – 1000	1-2 hrs
Irritation, dizziness	2300	5 min
Nausea	2300	30 min
Paresthesia, irritation	7200	8 min
Narcosis	8000 – 20000	30 min to 4 hrs
Immediately dangerous to life or health	> 50000	on exposure

Table 11-7: Acute effects and potential airborne concentrations; based on [Hall et al 1990]

Exhaustive toxicological information related to DCM is available e.g. from a “Toxicological profile for methylene chloride” [ATSDR 2000] or the IUCLID data set on dichloromethane [IUCLID 2000].

The following table is largely a summary of information provided in INEOS Chlor Guidance "Health & safety when working with methylene chloride". The references cited are:

- ECSA publication “Methylene Chloride: Properties, Uses & Impact on The Environment & Health” (1995)
- UK Health & Safety Executive, “Dichloromethane”, Toxicity Review No.12 (1985).
- Additional information about low level effects was sourced from:
- IPCS Environmental Health Criteria Monograph “Methylene Chloride” No. 164 (1996).

Concentration	**Effect**
200 - 300ppm	Odour threshold for most people. (At 250ppm odour is judged not unpleasant, but with rising concentration it becomes stronger and increasingly objectionable to most people.)
	Central nervous system starts to become affected by methylene chloride. (At very low levels minor effects on performance might be detected.)
300ppm+	At concentrations above 300 ppm and exposure times longer than 1hr significant decreased performance in neuro-behavioural tests is observed.
900ppm	Dizziness occurs.
1000ppm	Irritating to eyes. May cause conjunctivitis. Exposure to 1000ppm for 20-30 mins may cause lightheadedness.
~2000ppm	Symptoms of nausea, headache and vomiting may be experienced.
>2000ppm	Central nervous system becomes increasingly depressed producing numbness and tingling of the limbs.
15000ppm	Continued exposure will lead to unconsciousness and can prove fatal.

Table 11-8: Acute health effects of exposure to DCM

11.7 Laboratory test method for measurement of % weight loss of DCM based paint removers

Test Method: Rate of Evaporation of Dichloromethane Based Paint Removers No: 127/1

Apparatus

- Two flat bottom glass dishes (75mm dia. X 12mm depth)
- Glass hypodermic syringe without needle (10cm^3 capacity)
- 100cm^3 low form beaker

Method

Weigh to 4 decimal places the glass dishes. Place them in the fume cupboard (with the fan off) behind the draught screen.

Transfer approximately 80cm^3 of the paint remover under test to the beaker, behind the draught screen. Leave this for two minutes.

Withdraw into the syringe, at a rate of 1cm^3 per second, 10cm^3 of the sample. Weigh the syringe, upright after wiping any excess paint remover from the outside, to 4 decimal places.

Discharge the paint remover into the dish behind the draught screen at a rate of 1cm^3 per second. Reweigh the syringe. The point at which the syringe is half empty is the start time.

After 30 minutes, reweigh the glass dish.

Once the first dish has been filled with paint remover, refill the syringe and repeat the above procedure.

Calculation

Wt. of syringe full = W_1

Wt. of syringe empty = W_2

Wt. of dish empty = W_3

Wt. of dish full = W_4

% loss in mass = $((W_1-W_2) - W_4-W_3) \times 100) / (W_1-W_2)$

Reporting of Results

Report results as % w/w

11.8 Installations for paint removal

The following picture shows a typical industrial installation for paint removing with DCM containing paint strippers:

11.9 Evaluation of fatalities

The following tables show values reported from measurements in the context of fatal accidents that have been carried through in order to differentiate areas of different exposure levels.

Sample	DCM (mg/m³)
5–10 cm from liquid surface	> 14 000
25 cm from solvent surface	89 474
Brim of the tank 75 cm over surface	4 789
Surrounding air	243 -390

Table 11-9: Reference [Zarabeitia 2001]

Sample Location	DCM concentration (ppm)
3 m from the tank, 1.60 m high	192
1.3 m from the tank, 1.60 m high	167
0.30 m from the tank, 1.60 high	200
vertically over the tank, 1.60 high	224
0.40 m above the tank	477
in the tank, 0.13 m from the upper edge	12 060
in the tank, 0.40 m from the upper edge	14 540
in the tank, 0.68 m from the upper edge	14 540
in the tank, 0.50 m from the upper edge, tank stirred by means of a stripping brush	14 710

Table 11-10: Reference [Testud, Martin, Charretton 2002]

Another correlation can be shown with respect to agitation of the DCM containing liquid.

Sample Location (10.16 cm over liquid surface)	DCM (ppm)
Undisturbed	50
Agitated	>1256

Table 11-11: Reference: [Nowak, Hain, 1990]

The following table gives an over view on reported fatalities and selected severe intoxications.

Reference	Rel.	Year/ Country	Fatal	Non lethal	Age	Label/DCM content	Circumstances	Suggested impact		Health effects
								DCM	Other parameters	
private users										
[Logan, Victoria 2002]	yes	2000 UK	1		34	no data	restoring works in basement; 5 l of DCM containing stripper spilled		spilling in basement room with poor ventilation	
[Leikin, Kaufmann, Lipscomb 1990]	yes	1990 USA	2		29, 32	Seal -Off (91,2% DCM)	stripping paint in a small wash room	narcotic effect/poisoning	small room, poor ventilation; one victim wore a half mask with organic vapour cartridges	pulmonary oedema, haemorrhage, skin burns
[Frederick, Rudge 1990]	limited	1990		1	25	decreasing solvent	cleaning of computer equipment over 6-8 hours without protective equipment	elevated CO-Hb blood levels		headache, nausea, coordination problems, no pulmonary congestion!
[Buie, Pratt, May 1986]	limited	1986		1	34	Wonder Paste (toluol, methanol, acetone, methylene chloride)	stripping furniture for four days	elevated CO-Hb blood levels	poor ventilation	pulmonary oedema, pleural effusion
[Fagin, Bradley, Williams 1980]	limited	1980		1	20	no label	use of commercial paint stripper in poorly ventilated, unheated room for 1 hour	elevated CO-Hb blood levels	poor ventilation; no information whether any respiratory protection has been used	nausea, dizziness, unconsciousness
[Bonventre, Brennan, Jason 1977]	yes	1977 USA	1		13	no label	cleaning paint from bathtub	narcotic effect/poisoning	no information whether door was open or closed; open can of paint remover upright inside the bathtub, no protective equipment	oedema, diffuse visceral congestion
[Stewart, Hake 1976]	yes	1976 USA	1		66	no label (80% DCM)	paint stripping from chest of drawers in basement room (10.7x6.1x2.7m), heated by hot air from gas furnace for 3 hours	important rise of COHg blood levels after 3 hour exposure	no prior history of heart disease; no additional ventilation, no protective equipment, hot air from gas furnace	acute myocardial infarction

Reference	Rel.	Year/ Country	Fatal	Non lethal	Age	Label/DCM content	Circumstances	Suggested impact		Health effects
								DCM	Other parameters	
[Gerritsen, Buschmann 1960]	yes	1960 NL	1	1	52, 38	no data	remove paint from wood-work /remove paint from cupboard in unventilated basement room heated by kerosin stove	phosgen poisoning as combined effect of DCM and open flame	kerosin stove	pulmonary oedema, bronchiolitis
Total			**6**	**3**			**private user**			
professional use										
[Logemann, van der Smissen 1991]	yes	1991 DE	1		29	empty 10 kg tank of paint stripper (Fa. Hohmann) found in the car	stripping paint in small overfall basin (180x150x190)	narcotic effect/poisoning	poor ventilation; large amount of paint stripper; no information about any respiratory protection equipment	cerebral oedema, haemorrhage
[O'Neill, Rory 2003]	yes	1999 UK	2		42, 22	no data (DCM/HF)	immersing wheels in DCM, hydrofluoric acid and methanol containing tanks	narcotic effect/poisoning	ventilation not working; reaction of aluminium and HF heated the solution to the boiling point turning DCM to vapour; no information about any protection equipment	
[OHN 2002]	yes	2002 Australia	1		53	100 mm solvent	work at open dipping tank (3.7m x 0.9 m); concentrations over the tank at control up to 420,000 ppm	narcotic effect/poisoning	probably leaning over to scrub object by hand , no local exhaust ventilation, no mechanical lifting aid, no respiratory device	
[OHN-1 2002]	yes	2002 Australia	1		18	no data	work at open dipping tank	narcotic effect/poisoning	no protective equipment, no respiratory equipment, no mechanic ventilation, no mechanical lifting aid/dipping cage	
[Testud, Martin, Charreton 2002]]	yes	2002 FR	1		44	no label (81% DCM)	work at open dipping tank (120x320x90); concentrations over the tank probably > 30,000 ppm	narcotic effect/poisoning	probably leaning over to scrub the object by hand; high blood pressure; no protection equipment, no breathing mask, no ventilation device; but good natural ventilation	burns, diffuse visceral congestion

Reference	Rel.	Year/ Country	Fatal	Non lethal	Age	Label/DCM content	Circumstances	Suggested impact		Health effects
								DCM	Other parameters	
[Zarrabeitia 2001]	yes	2001 ES	1		27	700l of 125 Kwick Kleen (77%DCM)	work at open dipping tank (400x100x100); concentration over solvent surface 89,474->140,000 mg/m³ DCM	narcotic effect/poisoning	open tank, closed window; conventional half mask and 1 glove found in the tank, no mechanical ventilation device; leaning over the tank while trying to remove a broken glass from the tank bottom	cardio-respiratory arrest
[Fechner, Ortmann, Du Chesne 2000]	yes	2000 DE	1		22	Dirobal (85% DCM)	work in a room with filled open dipping tank (150x70x40); 2 filled open buckets, 1 closed barrel (150l) in the same room (3x4x2.5 m)	narcotic effect/poisoning	open tank, poor ventilation (electric fan switched of, window partially opened), no protection equipment	pulmonary, cerebral oedema, heart congestion
[Reinecke 1999]	yes	1999 DE	1			Anker; 80-90%DCM	stripping of paint in small bath room (1,45x2,80x2.64)	narcotic effect/poisoning	no protection equipment, no mechanic ventilation, window (0.53x1.26m) was opened; door was closed	
[Reinecke 1999]	yes	1999		1		no data	welding in basement rooms, while stripping in the open staircase	phosgen poisoning as combined effect of DCM and open flame	welding, no protection equipment, basement room with bad ventilation	pulmonary oedema
[Reinecke 1999]	yes	1999		1		no data	stripping of paint from a balcony floor (3.5 m²)	narcotic effect/poisoning	kneeling over the shortly before applicated paint stripper; open air working place; no information whether any respiratory protection has been worn	dizziness, unconsciousness
[Goullé, Lacroix 1999]	limited	1999 FR	1		47	**DCM Tank in production company**	inventory on DCM stock with pumping of DCM to additional tank; no paint stripper application	narcotic effect/poisoning	no protective equipment, no mechanical ventilation, solvent from (5-8000 L tanks) spilled on clay ground	haemorrhage, diffuse tissue congestion
[Tay, Tan, Sam 1995]	yes	1995 UK	1			No label data (75% DCM)	paint stripper (75% MC) used to soften hardened latex in a tank; breaching the authorised practice of the company	narcotic effect/poisoning	manhole upside, **no air blower inserted**, cartridge respirator and gloves not put on	haemorrhage, cerebral oedema

Reference	Rel.	Year/ Country	Fatal	Non lethal	Age	Label/DCM content	Circumstances	Suggested impact		Health effects
								DCM	Other parameters	
[Gisbau/ Wesermarsch]	yes	1989 DE	2		54,31	open 25 l tank; 9l applied	stripping paint from a ceiling	narcotic effect/poisoning	working overhead, insufficient protection masks, open 25 L can, 9L already applied; poor ventilation ! (door and windows covered with plastic)	
[Hall, Rumack 1990]	yes	1990 USA	2		21, 19	no data	work at open dipping tank	narcotic effect/poisoning	no respirator worn, ventilation exhaust system not working (case1), unknown (case 2)	multi-organ system failure
[Novak, Hain 1990]	yes	1985/87 USA	2		17, 21	no label (65-86% DCM)	work at open dipping tank (60x30x28 inches)	narcotic effect/poisoning	no information	burns, cerebral oedema, necrotizing pneumonitis
[Bonventre, Brennan, Jason 1977]	limited	1977 USA	1		20	no label; **degreasing solvent**	cleaning oil storage tank (1,6 m deep) from inside in basement of an apartment	narcotic effect/poisoning	work inside a tank, hole on top only (poor ventilation!!), two open solvent cans (3,7 l) in the room and on top of tank; no protective equipment, **no air blower inserted**	oedema, diffuse visceral congestion
[Schmidt, Raudonat 1990]	limited	1990 DE	1			no label (90% DCM); **cleaning solvent**	cleaning a tank of a tank truck	narcotic effect/poisoning	poor ventilation (opening on top of the tank); no protective equipment; no information that any kind of air blower has been used	suffocation; high DCM tissue levels
[Hahn, Michalak 2002]	yes	2002 DE	1		66	Colorex 31 (91% DCM)	stripping paint in unventilated room for more than 3 days. per day over several hours	no information on effects	no ventilation, mask only partially worn; health status not known	pulmonary oedema leading to acute respiratory distress syndrome (ARDS)
[Winek, Collom 1981]	yes	1981 USA	1		20	no label	immersing parts in solvent tank in small basement room ventilated by window over the tank	narcotic effect/poisoning	poor ventilation, (partially opened window over the tank); no protective equipment	bilateral pulmonary oedema, burns, high DCM blood levels
[Tariot 1983]	limited	1983		1	52	no label, 78% DCM	strip tank operator over 4 years			delirium
[Hall, Rumack 1990]	limited	1990		2	53, 34	no data	work at dipping tank/ applying paint stripper		no respiratory protection worn, no mechanical ventilation, small basement room with small open window above the open tank	generalized seizure, burns, unconsciousness, arrhythmias

Reference	Rel.	Year/ Country	Fatal	Non lethal	Age	Label/DCM content	Circumstances	Suggested impact		Health effects
								DCM	Other parameters	
[Stewart, Hake 1976]	limited	1976		1	35		experimental confirmation of correlation between COHg blood levels and DCM exposure			
[Manno, Rugge 1992]	limited	1992 IT	2			**mixed solvents**	burying barrels containing mixed solvents and solid waste in a well (2m below ground level)	narcotic effect/poisoning	no protective equipment, poor ventilation, concentration of DCM in the well	pulmonary and cerebral oedema, high DCM blood levels
[Shinomiya]	limited	Japan	1	1	39/41	80 ml DCM added as solvent to UNI-PROOF	pulverisation of paint (diluted with DCM as solvent) in sub deck sweet water reservoir of new vessel	narcotic effect/poisoning	poor ventilation under deck, 1 had no protective equipment, the gas mask (SAKAI-organic gas) of the other was found beside of him	
Total			**24**	**7**			**professional use**			

Table 11-12: Evaluation of severe and fatal accidents related to paint stripping with DCM containing paint removers