

Defra

**Risk Reduction
Strategy and Analysis
of Advantages and
Drawbacks for
Trichloroethylene**

Final Report - Stage 4

16 March 2005

Entec UK Limited

Report for

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Defra

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Final Report - Stage 4

16 March 2005

Entec UK Limited



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Executive Summary

Introduction

A European Union risk assessment has identified a need to limit the risks to the environment associated with manufacture, formulation and use of trichloroethylene as an intermediate in production of other chemicals and as a solvent vapour degreasing of metals. As such, the UK is required to develop a risk reduction strategy to effectively limit the risks.

Entec UK Limited has been commissioned under contract to the Department for Environment, Food and Rural Affairs (Defra) to undertake work in support of this risk reduction strategy.

This document is concerned with the development of a risk reduction strategy to address risks for the environment and for humans exposed via the environment. This document presents the final results in development of the risk reduction strategy following the approach set out in relevant guidance (European Commission, 1998).

The project was conducted in four stages. Stage 1 of the project involved data gathering and evaluation of all known uses of trichloroethylene, and establishment of the range of potential risk reduction options and current control measures in place. A report on Stage 1 was submitted in November 2004. Stage 2 of the work involved undertaking a systematic qualitative assessment of the advantages and drawbacks of a number of options for addressing the risks. A report on Stage 2 was submitted in January 2005.

Stage 3 of the work involved collating further information on the risk reduction options under consideration, including more detailed quantification and consulting with companies and organisations that had not previously been contacted. The outputs of Stage 3 included a semi-quantitative assessment of the advantages and drawbacks of the options considered. The Stage 3 report was agreed at a meeting of the steering group for this project on 2 March 2005. This report presents the final risk reduction strategy for trichloroethylene (Stage 4 of the work), and includes various amendments raised in the last steering group meeting.

Current Risk Reduction Measures

A range of existing risk reduction measures have been considered in order to set the identified risks in context, including:

- A prohibition on sales of trichloroethylene to consumers;
- Control of air emissions under the Integrated Pollution Prevention and Control, IPPC, regime (applies to trichloroethylene production, use as an intermediate and some metal degreasing operations);
- The solvent emissions directive (SED), which applies to metal degreasing where trichloroethylene consumption is greater than 1 tonne per year. This will require substitution of trichloroethylene, compliance with a strict emission limit, or a reduction in consumption which would likely preclude unacceptable risks to the environment;

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- The revised classification and labelling of trichloroethylene which requires substitution or enclosure of trichloroethylene processes where possible (under legislation such as the carcinogens directive);
 - Emission limits and quality standards for water; and
 - Workplace concentration limits.

It is considered highly probable that compliance with the requirements of the Solvent Emissions Directive will be sufficient to adequately limit the risks to the environment in relation to metal degreasing. This conclusion was agreed with the members of the steering group at a meeting in January 2005.

In addition, the Integrated Pollution Prevention and Control regime will impose (and is indeed currently imposing) additional controls on emissions, potentially including specific emission limits for trichloroethylene. Current emissions at production sites and those using trichloroethylene as an intermediate suggest that the risks at most sites are likely to be adequately controlled.

There is also a general trend away from the use of trichloroethylene. This is believed to be due to the revised classification and labelling of trichloroethylene (with consequences for other relevant legislation) and also the requirement to substitute trichloroethylene where practicable under the SED. The marketing and use restrictions for consumers also contribute to the reduction in use of the substance.

Overall, these measures have had and will continue to have a significant effect in reducing the environmental risks associated with the substance.

Assessment of Possible Further Risk Reduction Measures

It was agreed by the steering group for this risk reduction strategy that the following four risk reduction options should be considered in detail:

- ‘Do nothing’ option, relying on current legislation and its continuing implementation over the next few years.
- Emission limits or quality standards introduced through legislation and/or official guidance for implementation of that legislation (Solvent Emissions Directive, Integrated Pollution Prevention and Control).
- Marketing and use restrictions, extending the existing restriction upon use in consumer products.
- Voluntary emissions controls as an alternative to a legislative approach.

These options have been considered for each of the sectors where a need for limiting the risks has been identified. The relative advantages and drawbacks of these measures has been considered, based on a range of criteria set out in the Technical Guidance Document on Development of Risk Reduction Strategies.

For **production of trichloroethylene**, information has been provided by all of the EU-based producers on current emissions, and environmental concentrations in one case. By comparison

to the results of the risk assessment, it is considered likely that there have been significant reductions in emissions at some of the production sites. Therefore, it may be the case that emissions have already been limited sufficiently to remove the concern. However, emissions data would, of course, need to be properly verified.

These sites are already regulated under the IPPC regime and, irrespective of whether existing legislation is considered to be sufficient, it would also be appropriate to ensure that the relevant regulators of affected processes are fully aware of the conclusions of the environmental risk assessment in order to determine whether there is any potential to further reduce emissions, as well as to ensure that emissions are well controlled.

In **formulation for use as a solvent** (which is also taken to include repackaging/drum filling), information has been received from two non-producer companies that, between them, are believed to supply over two thirds of trichloroethylene used in non-feedstock applications in the EU. However, only a relatively small quantity of trichloroethylene actually undergoes 'formulation', with the remainder simply stored and repackaged for supply.

Formulation of trichloroethylene is not currently directly regulated under any Community pollution control regimes. There appear to be differences between the companies in terms of the level of controls on emissions and on whether emissions monitoring or estimation is undertaken.

The 'do nothing' option and that for voluntary emission controls are not considered to be sufficiently effective or practical for this use. The costs of marketing and use restrictions are considered to be disproportionate (although the operations in question could presumably be undertaken at existing production sites as an alternative to being undertaken at separate premises).

Since there remains uncertainty regarding whether emissions from these sites will actually pose an unacceptable risk for the environment, it is considered that the most appropriate option for this sector is likely to be as follows:

- For emissions monitoring to be required/undertaken in order to determine whether emissions from these sites are sufficient to pose concerns equivalent to those identified in the risk assessment (i.e. PEC/PNEC ratio >1). This need only be undertaken for the largest sites (e.g. handling over around 7,000 tonnes per year), given that smaller sites would be unlikely to pose an unacceptable risk to the environment based on the default worst-case emission factors used in the environmental risk assessment. Therefore, the costs of undertaking this monitoring would be expected to be moderate;
- If, following this monitoring, emissions are found to be sufficient to cause a concern for risks to the environment, it could be appropriate for legally binding limits on emissions to be introduced by the Member States (perhaps under a recommendation from the Commission). These limits could be regulated under the existing regimes established for air pollution control in the Member States.

For **metal degreasing**, it is considered that existing controls - the Solvent Emissions Directive in particular - are sufficient to adequately limit the risks for this application (when fully implemented by 2007). At the steering group meeting on 20 January 2005, members of the group agreed with this position.

In relation to **use as an intermediate**, the situation is similar to that for production sites: it is likely that, in general, emissions are currently lower than those considered in the risk assessment. However, emissions data were not available for all sites.

As with production sites, these sites are already regulated under the IPPC regime and it would be appropriate to ensure that the relevant regulators of affected processes are fully aware of the conclusions of the environmental risk assessment in order to determine whether there is any potential to further reduce emissions, as well as to ensure that emissions are well controlled.

Conclusions and Recommendations

For sites producing trichloroethylene and using the substance as an intermediate in the production of other chemicals, it is concluded that the most appropriate action would be to ensure that regulators under the IPPC regime take into account the conclusions of the environmental risk assessment in developing emission limits for sites. This should include consideration of whether techniques could be adopted under economically and technically viable conditions, taking into consideration the costs and advantages on a site-specific basis. It is also considered appropriate to apply the same approach for companies recycling trichloroethylene where covered by the IPPC regime.

For metal degreasing, it is concluded that there is likely to be no need for further risk reduction measures once the requirements of the Solvent Emissions Directive are fully implemented, by 2007.

In relation to sites undertaking 'formulation' or repackaging of trichloroethylene in significant quantities, it is concluded that there is insufficient information to determine whether existing risk reduction measures are sufficient. Therefore, it is concluded that the most appropriate strategy would be to:

- (a) Require that emissions monitoring be undertaken for the largest sites undertaking this activity (smaller sites are not expected to pose unacceptable environmental risks). This should be demonstrated to the satisfaction of the Commission or Member States, as appropriate.
- (b) For the Member States to introduce legally binding limits on emissions if current emissions are still found to pose an unacceptable risk to the environment. This requirement could perhaps be introduced under a Recommendation from the Commission.

It is considered that Community level legislation on emissions control is unlikely to be appropriate for this sector, given that the number of sites handling large quantities of trichloroethylene is low and that many processes will already be well controlled.

These conclusions were agreed at a meeting of the steering group for this risk reduction strategy on 2 March 2005.

It is recommended that the conclusions of this report are taken into account by the UK Government and the European Commission in determining the most appropriate strategy to address the environmental risks associated with trichloroethylene in the European Union.

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1. Background

1.1 Overview

Trichloroethylene is a colourless non-flammable liquid with an odour resembling that of chloroform. It is produced and used in large quantities within the European Union (total production in the EU was around 100,000 tonnes in 2003).

Trichloroethylene is on the first list of priority substances under the Existing Substances Regulation (EEC No 793/93). Under this Regulation, the UK is responsible for undertaking an EU-wide assessment of the risks of trichloroethylene for human health and the environment and, where appropriate, for recommending an EU-wide risk reduction strategy.

The risk assessment for trichloroethylene has been published (ECB, 2004). The aspects related to risks for the environment were developed by the Environment Agency for England and Wales and those related to human health were developed by the UK Health and Safety Executive. Both the human health and environmental parts have identified a need for limiting the risks associated with use of trichloroethylene in a number of different applications.

The Health and Safety Executive is developing a risk reduction strategy to address the risks to human health.

This document is concerned with the development of a risk reduction strategy to address risks for the environment and for humans exposed via the environment. The work is being undertaken by Entec UK Limited under contract to the Department for Environment, Food and Rural Affairs (Defra). This document presents the results of **Stage 4** (Final Report) in development of the risk reduction strategy following the approach set out in relevant guidance (European Commission, 1998).

Stage 1 of the project involved data gathering and evaluation of all known uses of trichloroethylene, and establishment of the range of potential risk reduction options and current control measures in place. A report on Stage 1 was submitted in November 2004. Stage 2 of the work involved undertaking a systematic qualitative assessment of the advantages and drawbacks of a number of options for addressing the risks. A report on Stage 2 was submitted in January 2005.

Stage 3 of the work involved collating further information on the risk reduction options under consideration, including more detailed quantification and consulting with companies and organisations that had not previously been contacted. The outputs of Stage 3 included a semi-quantitative assessment of the advantages and drawbacks of the options considered. The Stage 3 report was agreed at a meeting of the steering group for this project on 2 March 2005. This report presents the final risk reduction strategy for trichloroethylene (Stage 4 of the work), and includes various amendments raised in the last steering group meeting.

Following the completion of Stages 1, 2 and 3, comments from the project steering group were taken into account in order to allow progression of the next stage of work.

1.1.1 Structure of this report

The remainder of this section of the report provides a background to the uses of trichloroethylene. Section 2 summarises the results of the environmental risk assessment. Section 3 provides a discussion of some of the risk reduction measures currently in place. Section 4 includes a consideration of the range of possible further measures. Section 5 provides a qualitative analysis of the advantages and drawbacks of the identified risk reduction options. Section 6 provides conclusions and recommendations on Stage 2 of the work.

1.2 Use of Trichloroethylene

1.2.1 Production and Sales of Trichloroethylene

Trichloroethylene is produced mainly from ethylene or 1,2-dichloroethene by chlorination or oxychlorination using various catalysts. It may also be produced by oxychlorination of recovered residues derived from the vinyl chloride monomer manufacture and by the catalytic hydrogenation of tetrachloroethene (ECB, 2004). These production processes also produce tetrachloroethylene and are widely known as the “tri/per” process.

At the time that the risk assessment was undertaken, there were four companies producing trichloroethylene in the EU (ECB, 2004). There are considerably more companies listed as suppliers (i.e. all vendors, including distributors) in the IUCLID datasheet for the substance (ECB, 2000). A list of these companies by country is shown in the Table 1.1.

Table 1.1 Known Numbers of Companies Supplying Trichloroethylene by Country in 2000

Country	Number of Companies
Austria	1
Belgium	1
France	1
Germany	5
Italy	2
Netherlands	5
UK	1

Source: ECB (2000). The current number of suppliers is believed to be different compared to when this information was compiled.

There are currently thought to be three EU producers of trichloroethylene, with other companies supplying the substance but not producing it. These latter companies may include those that formulate the substance for use as a solvent (mixing trichloroethylene with small quantities of stabilisers, at typically less than 0.5%). One of the companies, based in France, has announced its intention to cease trichloroethylene production from 2006.

Historically, European production has been between 51,000 and 225,000 tonnes per year (based on data up to 1995 from the risk assessment). Since the mid 1970s, the use of trichloroethylene has declined by over 50% due to improved operating conditions leading to better solvent recovery and the use of other chlorinated solvents for metal cleaning. Hence, a considerable proportion of the reduction in production has been due to improved management practices, increased solvent recycling and waste management. However, there has also been a reduction in consumption (use) of trichloroethylene, especially in solvent degreasing. The reduction of sales is also believed to have been compounded more recently by the revised classification of the substance as a category 2 carcinogen. Western European sales in 2003 were only 38,000 tonnes and were 32,500 tonnes in 2004, significantly lower than sales in the recent past. The average annual change from 1998-2003 is -14.9% (ECSA, 2004).

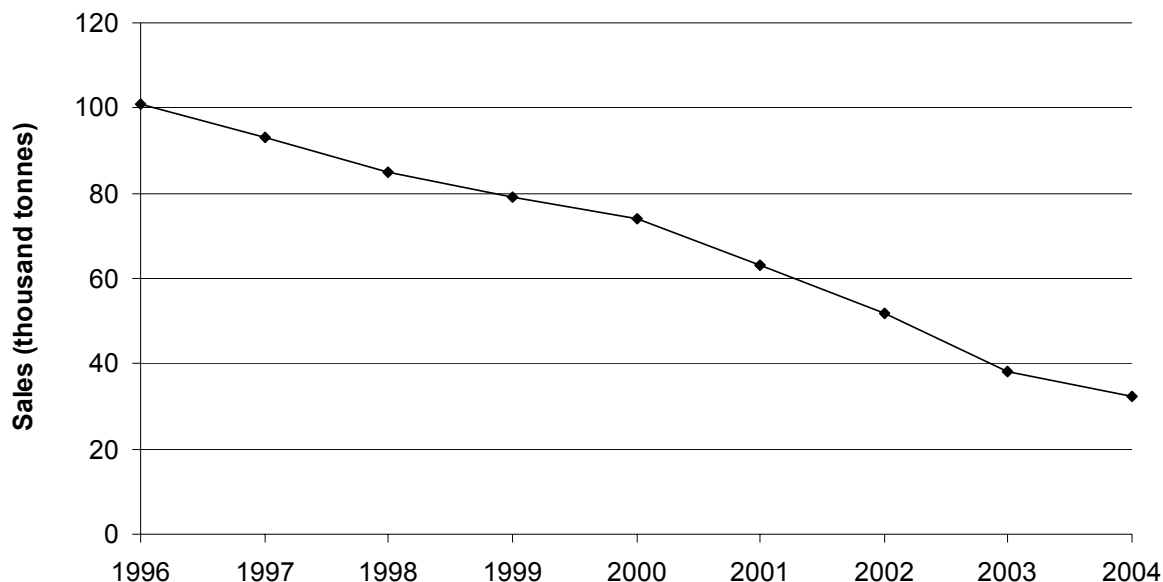
Table 1.2 Western European Sales for Trichloroethylene

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
TRI (kt)	101	93	85	79	74	63	52	38	33

Source: ECSA (2004, 2005).

Excludes sales for use as an intermediate. Data have been rounded.

Figure 1.1 Trend in Sales of Trichloroethylene 1998-2004 (ECSA, 2004 and 2004a)



The price of trichloroethylene is around \$US0.65 per lb (CMR, 2004). The price is reported to have remained constant at this level over recent years (Kirk Othmer, 2004). This equates to

€1078 per tonne or £744 per tonne¹. For the purposes of this risk reduction strategy, the market value is assumed to be €1100 per tonne. This is consistent with information provided by companies purchasing the substance for use in surface cleaning in the UK.

On this basis, sales of trichloroethylene onto the EU market excluding quantities used as a feedstock/intermediate are worth circa €32-42 million based on sales in 2003 and 2004.

The quantity sold for use as an intermediate in 2003 was 65,000 tonnes, with an associated value of €72 million per year, assuming the price is the same as that sold for other uses (in reality, the market may be worth slightly less than this given that larger quantities are likely to be used at each site in manufacture of other chemicals). Total sales in the EU could thus be worth just over €100 million per year.

Table 1.3 summarises uses of trichloroethylene sold into the EU market in 1996 and in 2003. As can be seen from this table, use in metal degreasing and adhesives has decreased significantly in both percentage and absolute terms over recent years, whereas use as an intermediate has increased in both absolute and percentage terms. Use as an intermediate is therefore expected to comprise the majority of the current EU market at present, whereas use in metal degreasing was previously the greatest application.

Table 1.3 Uses of Trichloroethylene Sold into EU Market in 1996 and 2003

Use	Percentage of Sales, 1996	Percentage of Sales, 2003
Metal degreasing in vapour degreasers	52%	28%
Adhesives	6%	3%
Consumer uses	4%	0%
Others	2%	2%
Feedstock (intermediate)	37%	67%
Total	100% (approx. 122,000 tonnes)	100% (approx. 96,000 tonnes)

Others includes extraction, leather preparation, pharmaceuticals.
Source: ECB (2004, 2004a).

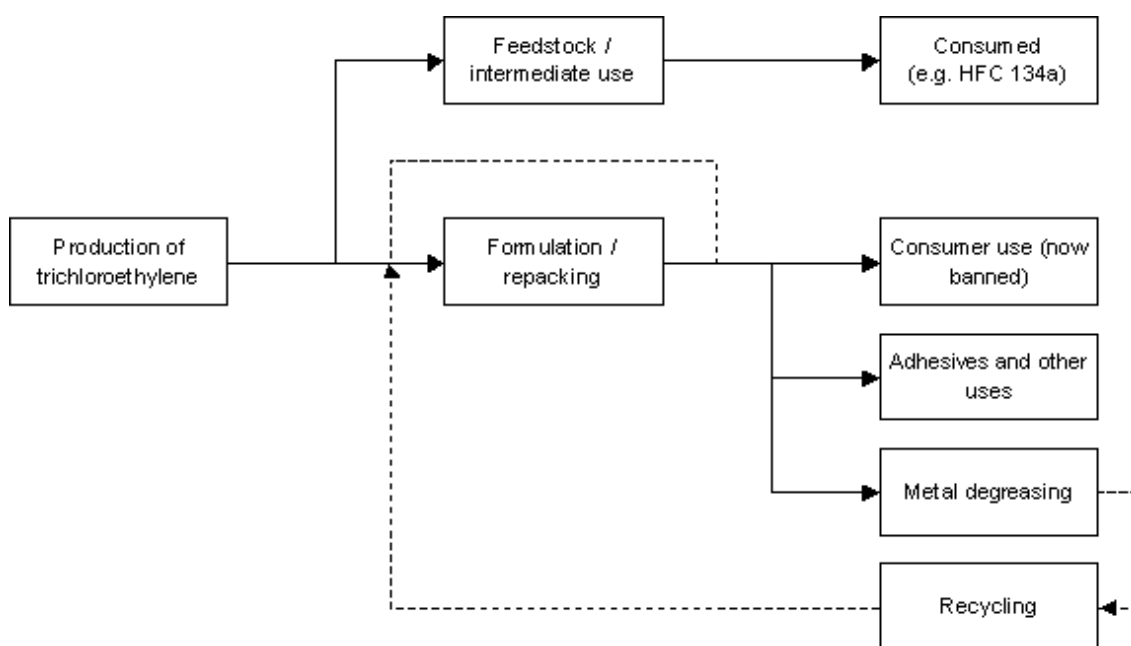
Figure 1.2 provides a summary of the key uses of trichloroethylene and key stages in the supply chain. The main uses are as a feedstock and in metal degreasing. Whereas feedstock use is often supplied directly by the producers of trichloroethylene (and is site-limited in some cases), other uses - particularly metal degreasing - are often supplied through one or more different links in the supply chain, including:

- Companies that store and repackage trichloroethylene, providing the product to markets requiring particular quantities (e.g. drums) or to markets in particular locations;

¹ Based on exchange rates of €0.75 per \$US and £0.52 per \$US on 2/12/04.

- Companies that add stabilisers to trichloroethylene in order to reduce photochemical or thermal decomposition; and
- Recycling companies that collect and recover trichloroethylene by distillation, particularly for use in metal degreasing.

Figure 1.2 Summary of Key Uses of Trichloroethylene



1.2.2 Use as an Intermediate

Trichloroethylene is used as a feedstock for CFC substitutes, HCFCs and HFCs. More specifically, it is used in the production of 1,1,1,2-tetrafluoroethane (HFC-134a, a HFC compound used as a refrigerant) and 1-chloro-2,2,2-trifluoroethane (HCFC-133a, a HCFC compound used to manufacture the anaesthetic ‘halothane’). The demand for trichloroethylene for this use has significantly increased after the Montreal Protocol where the use of CFCs was phased out. Other applications include use as an intermediate in the production of pentachloroethane (ECB, 2004).

In some cases, use as an intermediate in production of other chemicals (e.g. HFC-134a) takes place in the same location as production of trichloroethylene (though not necessarily by the same company).

1.2.3 Metal Degreasing

Trichloroethylene has a strong solvent action, a medium boiling point and high vapour density. It is used as an industrial solvent, primarily for vapour degreasing and cleaning of metal parts. More specifically, it is used for the removal of substances such as oils, greases, waxes and buffering compounds, or soils. After the Montreal Protocol in 1995 it has also been used as a replacement for 1,1,1-trichloroethane that has been largely phased out.

As can be seen from Table 1.4, the rate at which solvent is applied varies very significantly amongst companies. The data in this table are based on a survey by Envirowise (1997), in which some companies provided information based on consumption in litres per square metre and some in litres per tonne.

Table 1.4 Distribution of specific solvent consumption

	25% of companies use less than	50% of companies use less than	75% of companies use less than
Responses (in litres/m ²)	0.4	8	40
Responses (in litres/t)	8.1	53.3	174

Source: Envirowise (1997).

In 1994, HSE inspectors carried out a survey of vapour degreasing operations in UK factories. Detailed examinations of 120 degreasers using trichloroethylene showed that over 93% of the degreasers were traditional open-topped types. Some were provided with lids, covers and hoists. The survey concluded that the design of the degreasing plant had a number of problems that resulted in excessive solvent use, environmental and safety problems (due presumably to exposure to solvents) and increased costs. The types of problems noted are detailed in Table 1.5.

Table 1.5 Design feature needing improvement

Design feature	Degreasers needing improvement
Inadequate rim ventilation	67%
Hoist speed too fast	63%
Sited in potential draughts	60%
Inadequate topping-up method	60%
Inadequate freeboard ratio	51%
Unsuitable lid or no lid at all	36%

Source: Envirowise (1996).

Since this information was collated, significant improvements have been and are being made within the metal degreasing industry in order to comply with various pieces of legislation, particularly the Solvent Emissions Directive. Therefore, the above information is not likely to be representative of degreasing machines currently in use in the UK and also may not historically be true of machines in other countries.

As detailed in Section 3 of this report, the number of open type machines is now estimated to be significantly lower than when the above survey was undertaken, with companies using machines that enable compliance with relevant legislation (see Section 3.3.4).

A wide number of solvent cleaners have replaced the use of trichloroethylene for cold cleaning (e.g. with other hydrocarbons or aqueous solvents) and, in general, it is reported that most producers discourage the use of trichloroethylene as a cold cleaner, unless such use is strictly controlled². The amount of trichloroethylene used for hot vapour degreasing has been also reduced because of improved solvent recovery on hot vapour baths (ECB, 2004).

The metal finishing industry is characterised by a large number of small companies: Almost half the companies responding to an Envirowise questionnaire have fewer than 20 employees. 38% of companies have an annual turnover of less than £1 million (Envirowise, 1997).

Based on previous work undertaken for Defra by Entec (2002) for the UK Government, the surface cleaning sector is not a well defined sector but covers a wide range of operations and sizes of company. The number of installations expected to be covered by the SED is estimated at 4,600 (with 6,000 processes). Of the 4,600 installations affected in the UK, an estimated 1,840 (40%) were already regulated under the control of local authorities prior to introduction of the SED. The number of new installations affected by the SED in the UK was estimated to be approximately 2,760. Overall costs of compliance for the surface cleaning sector were estimated at £18.8 million (€26 million) per annum, a significant proportion of the overall costs of SED for the UK. This gives an average cost per installation of just over £5,000 (€7,000) per annum. It is estimated that the average cost per installation is £3,000 (€4,200) for solvent consumption of 1-5tpa; £5,200 (€7,200) for consumption of 5-10 tpa; and £6,500 (€9,100) for greater than 10 tpa.

1.2.4 Adhesives

Trichloroethylene is used as a solvent in certain adhesives due to the combination of its low flammability and drying time. Trichloroethylene based adhesives have historically been commonly used across a wide range of industrial applications. Additionally, trichloroethylene is often used as a cleaner provided with the adhesive. There were estimated to be 10-15 producers of adhesives containing trichloroethylene in the UK at the time the risk assessment was produced (ECB, 2004).

More recent information provided by the producers of trichloroethylene for this risk reduction strategy (ECSA, 2004a) suggests that there are now only a small number of adhesives formulators still using trichloroethylene, with the main use associated with underground rubber conveyor belting where flammability issues are of concern.

Information provided by the Association of European Adhesives Manufacturers (FEICA, 2004) confirms this view: discussions with one of the largest European adhesive manufacturers indicated that there is generally no trichloroethylene used anymore in adhesives production for products sold to the general public or to industry. Historical applications have been replaced through use of other solvents and new product generations based on aqueous products.

² In the context of this discussion, 'cold cleaning' relates to the method of cleaning - i.e. with a cloth or brush - as well as the temperature of cleaning.

1.2.5 Consumer Use and Other Uses

Trichloroethylene has been used as a solvent for various products (such as solvent based phosphating systems and for textile descouring), where it is recycled extensively. A significant amount of trichloroethylene was used directly by consumers, essentially for domestic textile “spot” cleaning, but this use has now been eliminated as a result of marketing and use restrictions (introduced due to classification as a Category 2 carcinogen). Its use as a dry cleaning agent is now limited, and it is no longer used as a ‘chain transfer agent’ in the production of polyvinyl chloride. It is also reported to have been used in the leather and textile processing industries and in the paint, lacquers and varnishes industry. In the past it has also been used as an anaesthetic, an extractant and a carrier solvent for pesticides and insecticides (ECB, 2004).

1.2.6 Recycling of Trichloroethylene

Appendix D provides information in relation to recycling of solvents and trichloroethylene in particular. Whilst this was not considered in the environmental risk assessment, some background information is provided here for information purposes. It is considered unlikely that recycling of trichloroethylene would lead to unacceptable risks to the environment given that current levels of emissions are relatively low and the market is not expected to increase significantly. However, it is evident that a significant quantity of trichloroethylene is currently supplied via recycling companies.

2. Risk Assessment

2.1 Hazardous Properties and Environmental Effects

2.1.1 Effects on the environment

The discussion in this section is based upon the EU risk assessment report (ECB, 2004).

Table 2.1 provides a summary of the key ecotoxicological endpoints used in the environmental risk assessment (ECB, 2004) for derivation of the 'predicted no effect concentrations' (PNECs) used in determining the need for limiting the risks.

Table 2.1 Ecotoxicological Endpoints Used in Risk Assessment for Trichloroethylene

Environmental Compartment	Endpoint	PNEC
Surface water	NOEC ^[1] 5.76 mg/l ^[2] fish (<i>Jordanella floridae</i>); 10 day larval survival.	115 µg/l using assessment factor of 50.
Wastewater treatment plants	IC50 13 mg/l methanogenic (methane producing) bacteria; 24 hour gas production	1.3 mg/l using assessment factor of 10.
Sediment	Derived by equilibrium partitioning method (using PNEC _{water})	316 µg/kg (whole sediment; wet weight)
Terrestrial compartment	Derived by equilibrium partitioning method (using PNEC _{water})	202 µg/kg (wet weight)
Terrestrial compartment (aerial exposure)	Plant lifetime study on tetrachloroethylene calculated by species sensitivity distribution HC5(50%) [3] of 41 µg/l.	6.5 µg/m ³ derived on molar basis by comparison with tetrachloroethylene (PNEC of 8.2 µg/m ³ is 4.9 x 10 ⁻⁸ mole/m ³)
Secondary poisoning	NOAEL ^[4] chronic exposure effects on kidney for mouse 50 mg/kg/day x 20 to convert to mg/kg food = 415 mg/kg	42 mg/kg assessment factor of 10 applied (as 52 week exposure)

[1] No observed effect concentration.

[2] Most sensitive of a number ends points in a 28 day fish early life stage (FELS) test.

[3] Hazardous concentration for 5% of species tested (with 50% confidence interval)

[4] No observed adverse effect level.

Source: ECB (2004).

As indicated in the environmental risk assessment, the classification of trichloroethylene in relation to environmental effects is as follows:

R52/53

Harmful to aquatic organisms; May cause long-term adverse effects in the aquatic environment.

2.1.2 Effects upon humans (relevant to exposure via the environment)

As detailed in the risk assessment (ECB, 2004), studies in experimental animals and humans have shown that trichloroethylene is rapidly and extensively absorbed by all routes of exposure. Human experience and limited animal experimental data indicate that liquid trichloroethylene is a skin and eye irritant.

The main toxic effect associated with acute inhalation exposure is central nervous system (CNS) depression. Exposure to very high concentrations causes narcosis. However, extensive experience in the use of trichloroethylene as an anaesthetic has demonstrated that recovery from narcosis is usually complete.

The repeated dose toxicity of trichloroethylene in humans has not been well characterised, although there is an extensive database of toxicological data (described in the risk assessment). Overall, based on the available information, functional CNS disturbance is regarded as a key endpoint in humans, although the available data do not allow conclusive judgements to be made regarding causal or dose-response relationships.

There appears to be an absence of CNS effects associated with exposure levels of around 50 ppm and taking a cautious approach, this value was identified as a NOAEL for functional CNS disturbance.

Kidney toxicity appears to be the most sensitive endpoint for both long-term repeated inhalation and oral exposure in animals. Because of the paucity of human data for this endpoint, the animal data have been considered in the risk characterisation, and a NOAEL of 100 ppm is identified for kidney toxicity.

The genotoxicity of trichloroethylene has been extensively investigated in experimental test systems. Trichloroethylene tested positive in a bacterial (Ames) test and a mouse lymphoma gene mutation assay, demonstrating that trichloroethylene is an *in vitro* mutagen.

Occupational studies did not provide complete reassurance of the absence of trichloroethylene-related carcinogenicity in humans. Given the observation of kidney tumours in animal studies and absence of convincing evidence that these arose by mechanisms not applicable to humans, together with the uncertainties regarding the human data, it was considered that there remains some concern for potential carcinogenicity in humans.

2.2 Environmental Exposure Assessment

2.2.1 Environmental releases of Trichloroethylene

The most significant exposure route to the environment and man via the environment is by the aerial route.

Releases of trichloroethylene may be from point or diffuse sources. Point source releases of trichloroethylene may occur from production and handling of trichloroethylene and through its use as a chemical intermediate. Other releases of trichloroethylene are from its use as a metal degreasing agent, in adhesives and limited consumer use as a solvent (though the latter use is now prohibited, as described in Section 3). As these releases are likely to occur from many different sites release is considered to be diffuse on a regional scale.

Section 1 of this report reviewed the situation with respect to current production and use of trichloroethylene in the EU. It was concluded that there has been a continued decline in the production and use of trichloroethylene. The main releases to the environment continue to be from production and its use as an intermediate (e.g. for the manufacture of HFCs and HCFCs) and from metal degreasing (including formulation).

Releases to the environment are from production and uses are reviewed in turn below.

Production

With regard to the production of trichloroethylene, estimates of releases to the aquatic environment range from 6.4×10^{-4} to 0.83 kg/tonne for the local scale (i.e. from individual sites). The largest individual release from production sites of 13.7 kg/day (over 365 days) and the sum of releases from other sites (i.e. 10.9 kg/day) were used for exposure calculations in the EU Risk Assessment. By comparison, releases to the atmospheric compartment are much greater and therefore more significant. Emission factors from the USA for releases to air were estimated at 2.07 kg/tonne. In the EU Risk Assessment, information from the EU was not separated between production and processing as an intermediate, however the largest single release was reported to be 879 tonnes/year which equates to 2.93 tonnes per day (over 300 days). A need for limiting the risks was identified using data from two sites, based on site-specific data.

Trichloroethylene can be formed during production of tetrachloroethylene by oxychlorination of ethylene dichloride and has been used in the production of PVC. Emission factors are available for these releases from the USA, but no information is available about the amounts of these chemicals produced by direct chlorination in Western Europe.

Use as an intermediate

Trichloroethylene is used in the production of HFC 134a (1,1,1,2-tetrafluoroethane) which is used as a refrigerant and HCFC 133a (1-chloro-2,2,2-trifluoroethane) which is used to manufacture the anaesthetic 'halothane'.

Estimates of emissions to air were based on the default value from the Technical Guidance Document on risk assessment of 0.1%. Some site-specific data indicated lower emissions of up to 74 g/tonne although the data were not considered to be sufficiently representative.

Handling

Emission losses from handling were based on site-specific information for a site not producing trichloroethylene. They were considered to apply to sites where trichloroethylene is formulated for solvent use (this is understood to relate to formulation with additives such as stabilisers, prior to sale for use as a solvent). The realistic worst-case emission factors were 0.4% to air and < 0.00025% to water.

For the purposes of this risk reduction strategy, consideration has been given to sites that formulate trichloroethylene and which repackage the substance at the same site. Only sites handling large quantities (several thousand tonnes per year) are likely to have the potential to cause unacceptable risks for the environment³.

³ Based on the realistic worst case assumptions on losses from these operations considered in the risk assessment (i.e. a loss to air of 0.4%).

Use in metal degreasing

The Risk Assessment assumed that 82% of trichloroethylene sold was used for metal degreasing and that 70% of trichloroethylene used during metal degreasing was released during use. Although there is not a “typical” metal degreasing site in terms of its size and the quantity of trichloroethylene used, it was assumed that there is range of plant sizes, and that larger sites (with a greater consumption of trichloroethylene) are more likely to have control measures in place to reduce emissions whereas smaller sites are less likely to have such control measures. The Risk Assessment estimated that 20 tonnes of trichloroethylene per year are used at a typical degreasing plant. The release of trichloroethylene was calculated based on release of 70% of the amount used with 90% of trichloroethylene released going to air and the remaining 10% going to water. The releases to the local environment were assumed to occur over 300 days per year. Regional and continental releases were calculated based on release for 365 days per year.

Release during formulation of adhesives

The Risk Assessment assumed that 9% of trichloroethylene sold (6,930 tonnes per year) was used for adhesives and associated cleaners. In the UK, 1,000 tonnes per year of trichloroethylene was used in the production of adhesives at between ten and fifteen sites. It was assumed that this situation was typical of the whole of the EU and that 100 tonnes per year is used at a typical site. Release of trichloroethylene during formulation of adhesives was calculated using default release factors in the TGD for risk assessment.

As detailed in Section 1 of this report, use in adhesives is now thought to have decreased significantly since the risk assessment was undertaken. However, since no need for limiting the risks is identified for this use, the implications of this reduction in consumption has not been investigated further for the purposes of the risk reduction strategy.

Consumer use

Consumer use of trichloroethylene accounted for 6% of sales (4,620 tonnes per year) at the time the risk assessment was produced. No information was available regarding the number of sites where trichloroethylene was used to make consumer products or how much is used at each site. It was therefore assumed that, as for adhesives, there are ten sites in each region. Releases of trichloroethylene during formulation of consumer products were estimated using the default emission factors from the TGD.

Consumer uses include ‘spot cleaning’ fabrics, home use, etc. It was reported that consumer use was largely restricted to France, Belgium and Italy, where the product could be purchased in some retail outlets. It was assumed that 100% of the trichloroethylene used in consumer products was released during use (90% to air and 10% to water). This is a diffuse release. The releases of trichloroethylene from use in consumer products were based on a population of 10,000 people in the local environment and 20 million people in the regional environment. Consumer use of trichloroethylene has now been prohibited (see Section 3).

Other uses

The remaining 3% of sales (2,310 tonnes per year) of trichloroethylene were for a range of uses including leather degreasing, as a carrier and general solvent and as an extractant. In the absence of further information it was assumed that 100% of the trichloroethylene used was released (90% to air, 10% to water). The releases were based on a local population of 10,000 people and a regional population of 20 million people (as required in the risk assessment TGD).

The releases from production and use with estimated and/or assumed emission factors are set out below in Table 2.2.

Table 2.2 Summary of atmospheric releases

Process	Emission factor	Release (kg/day)	
Production	0.21%	Local	2,930
		Regional	2,410
		Continental	214
Intermediate	0.1%	Local	67
		Regional	55
		Continental	68
Handling	0.4%	Local	400
		Regional	329
		Continental	627
Metal degreasing	70%	Local	42
		Regional	10,898
		Continental	98,083
Formulation (of adhesives)	2.5%	Local	8.3
		Regional	68.5
		Continental	406
Use of adhesives	100% of total used	Local	19
		Regional	1,899
		Continental	17,088
Formulation of consumer products ^[1]	2.5%	Local	3.85
		Regional	32
		Continental	285
Use of consumer products ^[1]	90%	Local	0.58
		Regional	1,139
		Continental	10,253
Other uses	90%	Local	0.29
		Regional	570
		Continental	5,126

Source: ECB (2004).

[1] Consumer use has now been prohibited.

2.2.2 Environmental Exposure

Trichloroethylene has a wide disperse use and, without adequate controls, is mainly released to the environment during use (excluding that which is used as an intermediate or where used in contained systems and subsequently disposed of). The major release is likely to be to the atmosphere and it was assumed in the risk assessment that 90% is released to air and 10% to water. Table 2.3 below sets of the predicted environmental concentrations (PECs) that were calculated and used in the risk characterisation of the EU RAR.

Table 2.3 Predicted Exposure Concentrations (PEC) for the Environment

Area	PEC value
Local	Air (site specific calculation) = 65 µg/m ³
	Surface water (site-specific calculation) = 66 µg/l
	Surface water (measured, representative) = 66 µg/l
	Agricultural soil (calculated) = 31 µg/kg
	Sediment (site-specific calculation) = 181 µg/kg
Regional	Air = 0.47 µg/m ³
	Surface water (measured, representative) = 0.35 µg/l
	Agricultural soil (calculated) = 0.008 µg/kg
	Sediment (site-specific calculation) = 0.9 µg/kg
Continental	Air = 0.18 µg/m ³
	Surface water (measured, representative) = 0.04 µg/l
	Agricultural soil (calculated) = 0.001 µg/kg
	Sediment (site-specific calculation) = 0.1 µg/kg

Source: ECB (2004).

2.2.3 Exposure of Man via the Environment

Within the EU risk assessment, the EUSES program was used to calculate the potential human intake of trichloroethylene on the regional scale, from exposure to background concentrations. The program uses the methods described in the risk assessment TGD to estimate the concentrations of trichloroethylene in foodstuffs (plants, milk and meat) from the calculated concentrations in air, water and soil. Standard daily intake values are then used to estimate the daily dose. For exposure on the local scale, concentrations measured in food and water were used in preference to the calculated values.

The daily human intake of trichloroethylene was estimated, based upon typical human consumption and inhalation rates. The total intake was calculated to be 1.45×10^{-4} mg/kg/day. Calculated regional concentrations and human intake via direct exposure is set out in table 2.4. As can be seen from this table, intake via air is responsible for around 90% of the total intake.

Table 2.4 Regional concentrations in air, water and biota and the calculated human intake

Concentrations in air, water and biota	Human consumption or intake rate per day	Human intake via indirect exposure (mg/kg/day) ^[1]
Air = 0.47 µg/m ³	20 m ³	Air = 1.3x10 ⁻⁴
Drinking water = 0.17 µg/l	0.002 m ³	Drinking water = 5.0x10 ⁻⁶
Fish = 6.1 µg/kg	0.115 m ³	Fish = 1.0x10 ⁻⁵
Leaf/Stem crop = 0.004 µg/kg	1.2 m ³	Stem of plants = 6x10 ⁻⁸
Root crop = 0.015 µg/kg	0.384 m ³	Root of plants = 8x10 ⁻⁸
Meat = 3 x 10 ⁻⁴ µg/kg	0.301 m ³	Meat = 1.4x10 ⁻⁹
Milk = 5 x10 ⁻⁴ µg/kg	0.561 m ³	Milk = 4x10 ⁻⁹
		Total = 1.45x10 ⁻⁴ mg/day

[1] Assuming a 70 kg person and intake of 100%

Source: ECB (2004)

In addition to predicted exposure at the regional level, the risk assessment reported predicted local exposures with worst-case concentrations in air, drinking water and foodstuffs from literature values (shown in table 2.5 below). Again, EUSES was also used to calculate local human exposure via the environment, but in each case values were lower than those using the worst case literature data.

Table 2.5 Local concentrations in air, water and food and the calculated human intake

Concentrations in air, water and biota	Daily human consumption or intake	Calculated human intake via indirect exposure (mg/kg/day) ^[1]
Air = 65 µg/m ³ (PEC _{local,air} measured near a production plant)	20 m ³	0.019
Drinking water = 21 µg/l	0.002 m ³	6x10 ⁻⁴
Fish = 479 µg/kg	0.115 kg	7.9x10 ⁻⁴
Leaf/stem crop = 6 µg/kg	1.2 kg	1.0x10 ⁻⁴
Root crop = 6 µg/kg	0.384 kg	3.3x10 ⁻⁵
Meat = 192 µg/kg	0.301 kg	8.3x10 ⁻⁴
Milk/dairy products = 20 µg/kg	0.561 kg	1.6x10 ⁻⁴
		Total = 0.022 mg/kg/day

[1] Assuming a 70 kg person and intake of 100%

Source: ECB (2004).

Total environmental exposures of 1.45×10^{-4} mg/kg/day for the regional model and 0.022 mg/kg/day for a local model were estimated (see tables 2.2 and 2.3). The local intake is dominated by a predicted environmental concentration in air of 0.065 mg/m³ leading to an inhalation contribution to body burden of 0.019 mg/kg/day (see 2.2.3). The regional intake is similarly dominated by exposure via air.

2.3 Environmental Risk Characterisation

2.3.1 Environment

Exposure concentrations were calculated for each of the environmental compartments at local, regional and continental scales. The predicted no-effect concentration (PNEC) and the predicted environmental concentration (PEC) for each environmental compartment were set out in tables 2.1 and 2.3, respectively. By comparison of these tables it can be seen that the only risk ratio (i.e. PEC/PNEC) that is greater than unity (i.e. that indicated a need for limiting the risk) is that for aerial exposure to plants. This risk arises from production sites (PEC/PNEC = 10), use as an intermediate (PEC/PNEC = 2.5), handling (formulation as a solvent) (PEC/PNEC = 14) and metal degreasing (PEC/PNEC = 1.5). These are detailed in Table 2.6.

Table 2.6 Processes with a Need for Limiting the Risks (Atmosphere Only)

Process	PEC _{local air} (µg/m ³)	PEC/PNEC
Production - largest site specific	65	10
Use as an intermediate	16	2.5
Handling (formulation as a solvent)	92	14
Metal degreasing	10	1.5

2.3.2 Humans Exposed via the Environment

Regarding acute toxicity, the NOAEL for CNS depression in humans for exposures of up to 8 hours is 300 ppm, equivalent to a body burden of 235 mg/kg/day. This is several orders of magnitude above the predicted body burdens arising from regional and local environmental exposures and thus does not raise concerns for human health.

For irritation, the skin and eye irritation potential relates to liquid trichloroethylene and therefore this endpoint is not relevant to environmental exposures.

For repeated dose toxicity for functional CNS disturbance, the human NOAEL of 50 ppm equates to a body burden of 38 mg/kg/day. For kidney toxicity, the NOAEL of 100 ppm for the rat equates to a body burden of 65 mg/kg/day. These are at least three orders of magnitude above the predicted body burdens arising from regional and local environmental exposures and thus do not raise concerns for human health.

For carcinogenicity and mutagenicity endpoints, there is no identifiable threshold exposure level below which the effects would not be expressed, so there are health concerns at all exposure

levels. Nevertheless, the predicted regional and environmental exposures are very low. Therefore, although there may be some residual risk of mutagenicity and/or carcinogenicity, this is likely to be very low. The EU risk assessment recommends that this should be taken into account when considering the adequacy of existing controls and the feasibility and practicability of further specific risk reduction measures.

It is noted that exposure of humans via the environment is significantly lower than for some of the direct human exposure routes. For example, exposure during adhesive manufacture was predicted to be 135 mg/kg/day where *local exhaust ventilation is not used*. This is around 6,000 times the level of exposure via the environment for the local model.

Therefore, within the risk assessment, it was indicated that “...*the predicted regional and environmental exposures are very low... [the risk] is likely to be very low*” (ECB, 2004). ***Given the low level of risk identified for humans exposed via the environment, the key driver for the environmental risk reduction strategy is considered to be the conclusions in relation to environmental exposure and the risk of harm to plants, rather than for humans exposed via the environment.***

2.4 Human Health Risk Assessment and Management

The risk reduction strategy for human health is currently being developed by the Health and Safety Executive. HSE is included on the steering group for this environmental risk reduction strategy.

A risk reduction strategy was originally proposed in 2002⁴ in relation to the risks for workers, covering manufacture and recycling of trichloroethylene; HCFC 133a/HFC 134a manufacture (intermediate use); metal cleaning; adhesives manufacture; and adhesive use (industrial).

It was concluded that the lead health effects of mutagenicity and carcinogenicity largely dominate the RAR risk characterisation for all exposure scenarios for workers.

The current EU legislation for worker protection was deemed to provide an effective framework for limiting the risks to human health from exposure to trichloroethylene in the sectors of interest. In addition the substitution requirement and the fugitive emission limit values required under the Solvents Emissions Directive (SED) will have an impact on workplace control. These measures would be further supported by:

- Introducing an EU harmonised OEL to help define adequate control;
- Development of statements of best practice for control of exposure; and
- Adoption of an industry standard for biological monitoring between the relevant industry sectors involved.

A revised risk reduction strategy will be prepared by HSE, taking into account more recent data on usage patterns (expected to be produced during 2005).

⁴ Risk reduction strategy for trichloroethylene (CAS RN 79-01-6) proposed by Member State Rapporteur UK, DOC ENV/D/430061/02, European Commission, Directorate General Environment, 11 February 2002.

3. Current Risk Reduction Measures

3.1 Overview

Table 3.1 summarises some of the existing measures in place to address the environmental and human health risks associated with trichloroethylene. These are discussed in turn in the following sections.

Table 3.1 List of Current Risk Reduction Measures in Place

Current Measure	Life Cycle Stages Affected
Marketing and use restrictions	Consumer use
Integrated pollution prevention and control	Production of TRI; use as an intermediate; formulation (potentially)
Solvent emissions directive	Metal degreasing
Classification and labelling	All production and use
Emission limit values and quality objectives	All production and use
Workplace concentration limits	All production and use
National legislation	Varies

3.2 Marketing and Use Restrictions for Consumers

Directive 76/769/EEC allows for the introduction of a wide range of possible controls on substances through inclusion on Annex I to the Directive. Specific restrictions are generally specified for individual substances.

Directive 2003/36/EC⁵ introduces specific marketing and use restrictions for certain substances that are carcinogenic, mutagenic or toxic to reproduction. Trichloroethylene is included within this Directive because it is classified as a Category 2 carcinogen (see Section 3.5). As such, it must not be used in substances and preparations placed on the market for sale to the general public. As detailed in the risk assessment report, around 6% of EU sales previously went into consumer uses, particularly for spot cleaning of fabrics.

In addition to removing the health risks to consumers associated with cleaning of fabrics, this legislation will also reduce environmental risks due to the decreased levels of production - resulting in a reduced emission to the environment - and through reduction in use by consumers

⁵ OJ L 156, 25.6.2003, p. 26.

with subsequent disposal (some trichloroethylene products were reportedly sold to consumers without instructions on use (ECB, 2004)).

3.3 Control of Air Emissions under IPPC

All sites producing trichloroethylene and using it as a feedstock in production of other chemicals are expected to be covered by the Integrated Pollution Prevention and Control regime. In addition, a number of metal degreasing sites are covered by the requirements of the IPPC Directive⁶.

Integrated Pollution Prevention and Control was introduced through Directive 1996/61/EC. The IPPC Reference Document on Best Available Techniques (BREF) in the Large Volume Organic Chemicals (LVOC) Industry (European Commission, 2003) has been consulted in order to review guidance on emission limits for the production of trichloroethylene and its use as an intermediate in the production of other chemicals, such as HFC and HCFCs.

The BREF notes that the UK has indicated that best available techniques (BAT) can be used on point releases of different classes of VOCs from new processes to achieve so-called 'Benchmark Levels' (country-specific guidance may override the EU benchmark levels). The German TA-Luft classification system is used by several member states as a basis for permitting and national legislation or guidance. It is also the basis for a system developed in the UK (the Environment Agency, as cited in the BREF Note) that identifies three classes of VOC and requires a commensurate level of prevention and control of each class (the UK classification system is expected to be revised in the near future). The three classes are currently:

- Extremely hazardous to health - such as benzene, vinyl chloride and 1,2, dichloroethane
- Class A compounds - that may cause significant harm to the environment (e.g. acetaldehyde, aniline, benzyl chloride)
- Class B compounds - that have lower environmental impact.

Under the currently published UK Benchmark levels for BAT (Environment Agency, 1995), trichloroethylene is considered as a Class A compound which equates to a class I organic compound under TA luft. Therefore, a benchmark emission level of 20 mg/m³ would apply to a mass threshold flow of greater than 100 g/h, (≥ 100 g/h under TA luft). It is of note, however, that since its reclassification as a Category 2 carcinogen, trichloroethylene would be classified as 'extremely hazardous to health'. For such substances, the BREF indicates that individual guidance levels are provided in the UK's process guidance will apply (this is expected to correspond to the 2 mg/m³ required under the Solvent Emissions Directive). The BREF also notes that although LVOC processes are not covered by the scope of the Solvent Emissions

⁶ Including installations for surface treatment of metals and plastic materials using an electrolytic or chemical process where the volume of the treatment vats exceeds 30 m³ (part 2.6 of Annex I to the Directive); and installations for the surface treatment of substances, objects or products using organic solvents, in particular for dressing, printing, coating, degreasing, waterproofing, sizing, painting, cleaning or impregnating, with a consumption capacity of more than 150 kg per hour or more than 200 tonnes per year (part 6.7 of Annex I). Other activities with a technical connection to these activities will also be covered.

Directive (1999/13/EC), that Directive nonetheless provides some useful guidance on the prevention and reduction of air pollution from solvent emissions. These are discussed in Section 3.4 and include substitution of and emission limits for risk phrase solvents. An emission limit of 2 mg/Nm³ applies for carcinogenic, mutagenic or toxic VOCs, where the mass flow exceeds 10g/h. For halogenated VOCs with risk phrase R40 an emission limit value of 20mg/Nm³ applies where the mass flow exceeds 100g/h (this would apply, for example, to tetrachloroethylene or methylene chloride).

Although the SED does not apply to production of trichloroethylene and use as an intermediate, for substances in general it is noted that the applicable emission limit values are the same as UK and German Benchmark levels associated with BAT (although the application of threshold mass flow is an order of magnitude lower). However, the emission limit for trichloroethylene, given the R45 risk phrase, is lower under the SED (2 mg/m³) and indeed this is reflected in the UK guidance (Defra, 2003) which overrides the EU-level guidance.

With regard to the calculated emission values in the Risk Assessment referred to in section 2 of this document, local scale emission rates of 2.93 tonnes/day (122,100 g/h) from production, 67 kg/day (2,791 g/h) from use as an intermediate and 400 kg/day (16,667 g/h) for handling are used. Comparing these levels with emission rates stated above for reduction using BAT (i.e. \geq 100 g/h) it is clear that large reductions on emissions should be achieved under IPPC, at least on point releases of trichloroethylene.

The BREF sets out, in some detail, techniques for the reduction of point source and diffuse (fugitive) emissions from different processes include releases from storage handling and transfer. The BREF states that process vents usually represent the largest source of VOCs arising from LVOC processes, and that VOCs should, wherever possible, be reused within the process. The potential for recovery will depend on such factors as:

- **Composition.** In technical and economic terms, a gas stream containing VOCs (or a simple mixture) will be more amenable to reuse than one containing a complex mix. Likewise, high concentration streams (with low levels of inerts) are more amenable to re-use.
- **Restrictions on reuse.** The quality of recovered VOCs should be of a suitable quality for re-use within the process and should not generate new environmental issues.
- **VOC value.** VOCs that are derived from expensive raw materials will be able to sustain higher recovery costs.

The next best alternative is to recover the calorific content of the carbon by using VOCs as fuel. If this is not possible then there may be a requirement for abatement.

3.4 Solvent Emissions Directive

3.4.1 General Overview of Legislation

Directive 1999/13/EC was implemented with the intention to prevent or reduce the direct and indirect effects of emissions of volatile organic compounds (VOCs⁷) into the environment and the potential risks to human health. It provides for measures and procedures to be implemented for the activities defined in Annex I to the Directive (where such activities are operated above certain solvent consumption thresholds).

Operators of new plant covered by the Directive have the following options:

- An emission limit compliance option involving either adherence to certain emission limits specified in relation to process and fugitive⁸ emissions; or
- A 'reduction scheme' where emissions reductions at least equivalent to those under the emission limit option are achieved through other means (this mainly relates to use of low VOC coatings).

All new qualifying installations (coming into operation after 11th March 1999) are required to comply with the main requirements of the Directive immediately and existing installations have until 31st October 2007 to comply with the majority of the requirements. Both new and existing installations covered by the Directive must be registered or undergo authorisation by the competent authorities in the Member States.

In addition to the main requirements on compliance with general emission limits for VOCs or the reduction scheme, there are specific requirements related to certain substances. Substances and preparations based on VOCs and classified as carcinogens, mutagens, or reproductive toxins⁹ are required to be replaced as far as possible by less harmful substances or preparations within the shortest possible time. Where the mass flow of these compounds is greater than, or equal to, 10 g/h, an emission limit value of 2 mg/Nm³ is specified (for the mass sum of the individual compounds).

For discharges of halogenated VOCs which are assigned the risk phrase R40, where the mass flow of the compounds is greater than, or equal to 100 g/h, an emission limit value of 20 mg/Nm³ applies. The discharge of the above types of compounds (often termed 'risk phrase solvents') is required to be controlled by use of contained conditions as far as technically and economically feasible to safeguard public health and the environment.

Specific application of the Directive to use of trichloroethylene is considered below.

⁷ VOCs include any organic compound having at 293.15 K a vapour pressure of 0.01 kPa or more, or having a corresponding volatility under the particular conditions of use.

⁸ Fugitive emissions are any emissions not in waste gases of volatile organic compounds into air, soil and water as well as solvents contained in certain products. They include uncaptured emissions released to the outside environment via windows, door, vents and similar openings.

⁹ Those required to carry the risk phrases R45, R46, R49, R60, R61.

3.4.2 Application of the Solvent Emissions Directive to Trichloroethylene Uses

The Directive applies to a range of activities that generally require significant quantities of solvents, including:

- A range of coating and coating manufacturing activities;
- Surface cleaning;
- Dry cleaning;
- Wood impregnation;
- Footwear manufacture;
- Rubber conversion;
- Vegetable oil and animal fat extraction; and
- Manufacture of pharmaceutical products.

In relation to the uses for trichloroethylene identified in the risk assessment, the specific activities and associated thresholds are as shown in Table 3.2.

Table 3.2 Activities Covered by SED and Relevant to Trichloroethylene

Activity	Solvent Consumption Threshold	Comments
Surface cleaning	> 1 tonne per year ^[1] > 2 tonnes per year (does not apply to trichloroethylene) ^[2]	Need for limiting the risks identified.
Adhesive manufacture	> 100 tonnes per year	No need for limiting the risk identified.
Adhesive coating	> 5 tonnes per year	No need for limiting the risk identified.
Other coating and coating manufacturing activities	Various	Use of trichloroethylene in such activities is no longer believed to occur ^[3] .

[1] Using solvents with risk phrases R45, R46, R49, R60, R61 or R40.

[2] Other surface cleaning.

[3] Other possible or previous uses identified in the risk assessment include use in solvent based phosphating systems, for textile desizing scouring, in leather preparation, the pharmaceutical industry and as a heat transfer agent. Also as a carrier solvent for pesticides, printing inks, varnishes and paints, as an anaesthetic and as a solvent for waxes, fats, resins and oils. It is of note that many of these would be covered by the Directive (if they were still to occur, which is not believed to be the case).

Therefore, the main area of use that will be affected by the Solvent Emissions Directive is use in metal cleaning¹⁰. Only this application has been considered at this stage of the risk reduction strategy.

During discussions of the steering group for this risk reduction strategy, the possibility was raised that there could exist the potential for a site to operate several metal degreasing machines, each with consumption below 1 tonne per year but with an overall consumption greater than the threshold (the site could potentially be exempt from the requirements of the Directive). However, in the UK at least, such sites should be controlled under the implementing regulations^{11,12} and would not be exempt. However, in the UK and elsewhere, the full interpretation of the Directive can only be given definitively by the courts.

3.4.3 Substitution of Solvents and Implications for Trichloroethylene

In the United Kingdom, Defra (2004) has provided guidance on how the 'shortest possible time' should be interpreted. In relation to substitution of these solvents, the decision is made for each individual case and is down to the regulator. The regulator takes into account:

- The views of operators contained in submitted substitution plans;
- Factors set out in the Directive including fitness for use, potential effects on human health and occupational exposure, potential effects on the environment, the economic consequences (in particular, the costs and benefits of the options available). This is done in relation to both the existing substances/preparations and their potential substitutes; and
- Any guidance published by the European Commission under Article 7.

However, substitution should normally be undertaken no later than 31st October 2007 for substances assigned the classification before 29th March 1999 and for other substances within six years of the date of assignment/reclassification.

Trichloroethylene is assigned the risk phrase R45 and is classed as Category 2 carcinogen; it is thus a substance that should be regarded as if it is carcinogenic to humans because there is sufficient evidence to indicate that exposure may result in development of cancer.

Therefore, there is a requirement for trichloroethylene to be replaced by less harmful substances in the shortest possible time. If the date when this classification was assigned is taken as the date of publication in the Official Journal, substitution should be undertaken no later than 28th

¹⁰ The definition of 'surface cleaning' under the Directive includes "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".

¹¹ The Solvent Emissions (England and Wales) Regulations 2004, S.I. 2004, No. 17.

¹² Because all machines would be served by the same 'activity' of trichloroethylene storage, which provides a 'technical connection' to each of the machines. Since the units would all be served by the same 'directly associated' activity, they should together be regarded as a single 'technical unit' under the SED. Further elaboration is provided in relevant UK Government guidance (Defra, 2003a).

January 2007. It should be noted, however, that this definition of “shortest possible time” is only relevant for the UK and does not apply to all other Member States.

3.4.4 Emission Limits under the Solvent Emissions Directive

In relation to surface cleaning under the Directive, the prescribed emission limits for waste gases and fugitive emissions are detailed in Table 3.3.

Table 3.3 Emission Limits for Surface Cleaning using Risk Phrase Solvents under the SED^[1]

Solvent Consumption	Emission Limit in Waste Gases	Fugitive Emission
1-5 tonnes per year	20 mg/Nm ³ 2 mg/Nm ³ where mass flow > 10g/h	15% of solvent input
> 5 tonnes per year	20 mg/Nm ³ 2 mg/Nm ³ where mass flow > 10g/h	20% of solvent input

[1] Only facilities using risk phrase solvents are included here (applies to trichloroethylene).

The emission limit for waste gases represents a significantly lower level of emissions that has been historically achieved in this sector. It is only generally achievable through use of closed cleaning machines.

Based on data from the ECSA (2001), it was estimated that a significant proportion of machines would need to be replaced in order to achieve compliance with the Solvent Emissions Directive. Table 3.4 summarises the types of surface cleaning machines, the estimated split according to types in 2000 and the relative emissions for tetrachloroethylene. Whilst these data are for tetrachloroethylene, they provide useful information on the split of different machine types used in the EU and the relative emissions of different machine types, which are expected to be similar for trichloroethylene. Therefore, they provide useful information for this risk reduction strategy for trichloroethylene.

Table 3.4 Summary of Surface Cleaning Machines in 2001 (relates to Tetrachloroethylene)

Type	Description	Estimated % in 2000 in Europe	Assumed Emission (kg/h)
Type I	Fully emissive open top		
Type IIA	Enclosed machine without activated carbon filter	8%	2 (40 times Type IV)
Type IIB	Enclosed machine with activated carbon filter	4%	1 (20 times Type IV)
Type III	Closed loop drying system with activated carbon filter	42%	0.155 (3 times Type IV)
Type IV	Closed loop drying system with activated carbon filter without exhaust air	47%	0.05

Source: ECSA (2001).

For trichloroethylene, the conclusion of a need for limiting the risks for surface cleaning in the risk assessment was based on an assumed open machine, where 70% of the total solvent use is released mainly to air. Therefore, if all sites were to implement closed machines (Type IV), the PEC/PNEC ratio for should, theoretically, be reduced to below unity, assuming a similar reduction in emissions for trichloroethylene as for tetrachloroethylene (of a factor of 40)¹³.

Since only closed machines will allow companies undertaking surface cleaning to comply with the Solvent Emissions Directive, it is expected that all such companies will have reduced their emissions to a level that would not lead to the conclusion that the environmental risks need to be limited¹⁴.

As a further confirmation of the effectiveness of this measure, an analysis of the emission limit value specified for waste gases has been undertaken. The applicable emission limit for trichloroethylene is 20 mg/Nm³.

The PEC value for atmosphere in the risk assessment is calculated according to the following relationship from the risk assessment Technical Guidance Document:

$$C_{\text{air}} = \text{Emission} \times C_{\text{std}_{\text{air}}} \quad [\text{equation 1}]$$

where:

$$C_{\text{air}} = \text{concentration in air at 100m from point source (mg/m}^3\text{)}$$

¹³ The PEC/PNEC ratio for the realistic worst-case site is 1.5. If this were reduced by a factor of 40, based on replacement of a totally open machine with a Type IV machine, the PEC/PNEC ratio could be reduced to as low as 0.04, indicating that the need for limiting the risks could be removed.

¹⁴ Whilst companies could theoretically reduce their trichloroethylene consumption to below 1 tonne per year and still use less advanced machines (they would be exempt from the Solvent Emissions Directive), such a low level of use would not be expected to lead to a PEC/PNEC ratio > 1 (the environmental risk assessment assumed a consumption of 20 t/yr and the PEC/PNEC ratio was only 1.5).

$$\begin{aligned} \text{Emission} &= \text{emission to air (kg/day)} \\ \text{Cstd}_{\text{air}} &= \text{standard concentration in air at source strength of 1 kg/s} \\ &\quad (2.78 \times 10^{-4} \text{ mg/m}^3) \end{aligned}$$

Taking the PNEC for trichloroethylene from the risk assessment of $6.5 \mu\text{g/m}^3$, the emission that would not lead to a need for limiting the risks would be 23.4 kg/day.

In order to emit this quantity of trichloroethylene and still comply with the emission limit, the volume flow of exhaust gas would have to be around 11.7 million m^3 per day or about $135 \text{ m}^3/\text{s}$. Such a large flow rate would not be expected from any metal degreasing operation and thus the emission limit specified in the Solvent Emission Directive is considered to be protective in terms of the environmental risks via the atmosphere compartment.

3.4.5 Summary and Effectiveness in Reducing Risks

Table 3.5 summarises the key requirements of the Solvent Emissions Directive in relation to emissions of trichloroethylene.

Table 3.5 Main Requirements of SED for Trichloroethylene in Surface Cleaning

Requirement	Details for Trichloroethylene
Threshold for inclusion	1 tonne per year
Emission limits (waste gases)	2 mg/Nm ³ (20 mg/Nm ³ where mass flow < 10g/h)
Substitution of solvents	Substitute trichloroethylene within the "shortest possible time"

Based on the above discussion, it is evident that implementation of the Solvent Emissions Directive will lead to significant reductions in emissions at those sites where emissions are currently less well controlled. It is likely that this will be sufficient to reduce the environmental risks to an 'acceptable' level.

A targeted investigation into large surface cleaning companies using trichloroethylene has been undertaken for the purposes of this risk reduction strategy (some of the largest UK users and emitters of trichloroethylene in this sector). Appendix A provides some information on individual companies, their likely responses to the SED, their current emissions and potential for achieving further emissions reductions.

Based on the information in this Section and that in Appendix A, the following can be concluded in relation to the effectiveness of the SED as a control measure for the risks identified for trichloroethylene:

- Of five large companies using trichloroethylene in metal cleaning and the supplier of metal cleaning machines contacted for the purposes of this risk reduction strategy, a number of options for compliance with the Directive have been identified. The key routes to compliance in relation to trichloroethylene are:

-
- a) substitution with alternative solvents that have a higher emission limit value;
 - b) reducing solvent consumption to below 1 t/yr to fall out of the scope of the Directive ; or,
 - c) reducing emissions to below the 2 mg/m³ level.

It appears that companies are in general attempting to undertake either (a) or (b) given that there are technically suitable alternatives for most applications (e.g. tetrachloroethylene) and given that existing metal cleaning machines significantly reduce consumption and hence emissions.

- The ‘realistic worst case’ PEC/PNEC ratio for surface cleaning is only 1.5. In order to comply with the emission limit under the Solvent Emissions Directive, companies emitting the largest amounts will need to significantly reduce their emissions and/or consumption of trichloroethylene. Reducing emissions to meet the limit of 2 mg/Nm³ is expected to be sufficient to limit the risks (emissions from a closed type machine are expected to be only 2.5% of those from open machines);
- If consumption of trichloroethylene is reduced to below the 1 t/yr threshold for inclusion under the SED, the risks can be assumed to be adequately limited: a consumption of 20 t/yr was assumed for the realistic worst case site in the risk assessment. Since the PEC value is linearly related to consumption in the risk assessment (excluding the minor contribution from the regional concentration), the PEC/PNEC value of 1.5 will be reduced to less than 0.1.

Therefore, it is considered highly probable that compliance with the requirements of the Solvent Emissions Directive will be sufficient to adequately limit the risks to the environment. This is expected to be true for other EU Member States, as well as the UK.

In relation to the risks for humans exposed via the environment, since there is no identifiable threshold exposure level for carcinogenicity and mutagenicity endpoints, the SED would not eliminate the identified need for reducing the risks. However, as discussed elsewhere in this report, the levels of human exposure are significantly lower than through other routes and so there is a significantly lower concern than for other human health endpoints. This is not, therefore, considered to be the main driving force for the environmental risk reduction strategy. In addition, the SED will tend to reduce such exposure further still.

3.5 Classification and Labelling of Trichloroethylene

3.5.1 Overview of Current Classification and Labelling

Table 3.6 summarises the current classification and labelling requirements for trichloroethylene. These requirements were fully introduced in the 28th Adaptation to Technical Progress¹⁵ of Directive 67/548/EEC of 28th January 2001.

¹⁵ OJ L 255, 21.8.2001, p. 1.

Table 3.6 Classification and Labelling Requirements for Trichloroethylene

Requirement	Description
<u>Classification</u>	
Carc. Cat 2; R45	May cause cancer (substances which should be regarded as if they are carcinogenic to humans).
Muta. Cat 3; R68	Possible risk for irreversible effects (substances which cause concern for humans owing to possible mutagenic effects).
R67	Vapours may cause drowsiness and dizziness.
Xi; R36/38	Irritating to eyes and skin.
R52-53	Harmful to aquatic organisms; May cause long-term adverse effects in the aquatic environment.
<u>Labelling</u>	
T	Toxic.
R: 45-36/38-52/53-67	As above
S: 53-45-61 ^[1]	Avoid exposure - Obtain special instructions before use. In case of accident or if you feel unwell seek medical advice immediately (show the label where possible). Avoid release to the environment. Refer to special instructions/safety data sheet.

[1] It is expected that a requirement for labelling as R68 will be introduced under a future adaptation of Directive 67/548/EEC.

3.5.2 Implications for Producers and Users

Under amendment to Directive 76/769/EEC (on marketing and use restrictions), trichloroethylene may not be used in substances or preparations on the market for sale to the general public, due to its classification as a Category 2 carcinogen (as discussed in Section 3.2);

Under Directive 98/24/EEC (the 'chemical agents directive'), employers are required to assess the risks to safety and health of hazardous chemical agents (which includes trichloroethylene) and to eliminate or reduce those risks to a minimum. By preference, substitution is to be undertaken, by replacement with a chemical or process that is less hazardous. If substitution is not possible, processes and equipment should be designed to avoid or minimise release and where this is not possible, collective measures such as ensuring adequate ventilation is required. The last option includes protection of individuals through personal protective equipment;

Under Directive 92/85/EEC (the 'pregnant workers directive'), exposure of pregnant workers is prohibited for all substances listed in Annex II to the Directive, and also before being listed in Annex II, all substances and preparations classified with R40, R45, R46 and R47. This includes trichloroethylene; and

Under Directive 2004/37/EC¹⁶ (the ‘carcinogens directive’), employers are required to reduce use of carcinogens and to replace them where technical possible by less dangerous substances. Manufacture and use must take place in a closed system (or exposure must be kept as low as possible where this is not feasible).

Also under the carcinogens directive, access to at-risk areas is restricted to those workers required to enter for their work or duties. Workers should not be permitted to eat, drink or smoke in places where there is a risk of contamination. Workers must to be provided with appropriate clothing and separate storage places for work clothing and for street clothes. Member States must also establish arrangements for monitoring the health of exposed workers and keeping a record of exposed workers for at least 40 years following the end of exposure. In addition, EU-wide limit values must also be adhered to. Upon request from the competent authority, employers must make available information on matters such as the reasons for using carcinogens, preventive measures taken and the number of workers exposed.

The requirements on substitution and enclosure of processes will have an effect upon the way in which trichloroethylene is handled within the workplace in all relevant life-cycle stages (as will the Solvent Emissions Directive, though only directly for use in metal degreasing). Of particular relevance, these requirements will also tend to reduce emissions of trichloroethylene to the environment from all stages. However, there does exist the potential, where sites are not covered by pollution control legislation, for emissions to the environment to increase: for example, increased ventilation of workplace air containing trichloroethylene to atmosphere would increase emissions to atmosphere (though this effect is likely to have little effect upon risks for the environment). Whilst it is not practicable to quantify the effect of these health-related measures upon emissions to the environment, the trend towards reductions in emissions to which these measures contribute has been taken into account in interpreting the likely current severity and urgency of risk reduction requirements for the environment.

3.5.3 Summary of Effectiveness in Reducing Risks

The key implications of the classification and labelling of trichloroethylene are as follows:

- There is a general requirement to replace trichloroethylene with less harmful substances through the Chemical Agents Directive, Carcinogens Directive and the Solvent Emissions Directive. For the latter, a timescale for substitution has been specified in the UK and this should be no later than 28th January 2007. Similar requirements are expected to apply in other Member States; and
- Where such substitution is not possible, there is a requirement that processes using trichloroethylene should generally be closed processes.

Whilst there are provisos in relation to technical and financial suitability as well as health and environmental effects of substituting and enclosing processes, the legislative requirements are generally expected to provide a significant level of control on the processes involved and emissions to the environment (due to enclosure of processes).

¹⁶ Replaces the previous carcinogens directive 90/394/EEC.

3.6 Emission Limit Values and Quality Objectives

Directive 90/415/EEC specifies emission limit values for trichloroethylene. The Directive is a daughter directive under Directive 76/464/EEC (the 'dangerous substances directive'). The emission limits are summarised in Table 3.7.

Table 3.7 Emission Limit Values for Trichloroethylene for Water^[1]

Plant Type ^[2]	Type of Average Value	Limit value by weight (g/t) ^[3]	Limit value by concentration (mg/l)	Date for compliance
Trichloroethylene and perchloroethylene production	Monthly	10	2	1 Jan. 1993
		2.5	0.5	1 Jan. 1995
	Daily	20	4	1 Jan. 1993
		5	1	1 Jan. 1995
Use of trichloroethylene in metal degreasing (where discharge exceeds 30 kg/yr)	Monthly		0.1	1 Jan. 1993
	Daily		0.2	1 Jan. 1993

[1] Where process involves open air agitation of effluents, compliance is required upstream of the plants concerned and that all waters likely to be polluted are properly taken into account.

[2] A simplified monitoring procedure may be applied where discharges do not exceed 30 kg/yr.

[3] Limit values relate to overall trichloroethylene plus perchloroethylene production.

In addition, an environmental quality objective of 10 µg/l was set for inland surface waters, estuary waters, inland coastal waters and territorial waters. This was to be complied with from 1st January 1993.

Under the Water Framework Directive (2000/60/EC), the requirements of Directive 90/415/EEC will be repealed and environmental objectives established under the first 'river basin management plan' required by the Directive must, as a minimum, give effect to quality standards at least as stringent as those required to implement Directive 76/464/EEC. However, emission limits for water may not necessarily be included.

Based on a 'non-paper' produced by the European Commission (2004a), the controls currently being considered are an environmental quality standard for trichloroethylene of 10 µg/l as an annual average for inland water, transitional water, coastal water and territorial water. This is equivalent to the standard under Directive 90/415/EEC. However, this does not represent an official position of the European Commission.

3.7 Workplace Concentration Limits

A range of occupation emission limits have been established in the Member States. These have been summarised by the ECSA as shown in Table 3.8.

Table 3.8 Occupational Exposure Limits in Various Member States

Country	OEL (TWA) ^[1]	STEL
Austria	50 ppm	250 ppm
Belgium	50 ppm	200 ppm
Denmark	10 ppm	-
France	75 ppm	200 ppm
Germany	50 ppm	250 ppm
Italy	50 ppm	100 ppm
The Netherlands	35 ppm	100 ppm
Sweden	10 ppm	25 ppm
Switzerland	50 ppm	250 ppm
United Kingdom	100 ppm (MEL) ^[2]	150 ppm

Source: ECSA (2001a).

[1] OEL (TWA): Occupational Exposure Limit (Time Weighted Average): 8 hours per day. STEL: Short Term Exposure Limit (15 minutes). MEL: Maximum Exposure Limit. Note that the MEL and OEL values are not directly comparable and a MEL places a duty on the employer to reduce exposure to a level that is as low as is reasonably practicable, and in any case below the MEL. In practice, therefore, the levels may be significantly lower than 100 ppm.

[2] In the UK, it is anticipated that the current system in which there are two types of OEL (MELs and Occupational Exposure Standards, OESs), will be replaced by a single type of OEL, to be called a Workplace Exposure Limit (WEL). This will impose a single duty on employers in that the amount of a chemical in their workplace air must not exceed the WEL. The WEL proposed for trichloroethylene is currently the same as that quoted above, but there is a need to determine whether determined whether industry can control to a more stringent level, given the reclassification as R45 (HSE, 2003).

Whilst these measures do not specifically target the risks for the environment (or for humans exposed via the environment), the measures taken to comply with these limits - such as enclosure of equipment - will also serve to reduce emissions to the environment. However, in some cases, increased ventilation of workplace air to atmosphere could actually increase emissions to the environment as compared to other containment or recovery options.

3.8 National Legislation

3.8.1 Sweden

Under the Swedish *Regulation on Certain Chlorinated Solvents* (1991:1289), occupational use of trichloroethylene (and methylene chloride) has been prohibited as of 1st January 1996. The National Chemicals Inspectorate (Kemi) has decided upon regulations on exemptions from this prohibition. Kemi specified a number of special reasons that users would have to demonstrate in order to continue using trichloroethylene, including:

- The company must be continuing to investigate feasible alternatives;
- No practicable alternative is available for the particular application; and
- Use does not entail excessive exposure.

The European Court of Justice examined this issue in 2000 provided a ruling¹⁷ on this national legislation. Whilst it was established that the ban is, in principle, a quantitative restriction within the meaning of the EC treaty, it was deemed to be justified on the grounds of protection of health of humans. A ban with the given possibilities for exemptions under the given conditions was stated to offer protection for workers whilst at the same time taking into account companies' need for continuity.

For the purposes of this risk reduction strategy, the producers of trichloroethylene have indicated (ECSA, 2004a) that the ban in Sweden may have reduced the market penetration of enclosed machine technology for the uses where it is still permitted under a derogation (making the associated emissions greater in some cases).

No other national legislation restricting the marketing and use of the substance has been identified amongst EU countries (other than implementation of European legislation on consumer use). Member States are all required to implement legislation such as the Solvent Emissions Directive and Integrated Pollution Prevention and Control Directive through their own national legislation and this is not considered specifically here.

3.9 Conclusions on Existing Measures

As detailed above, there is a range of existing measures in place that will ultimately serve to significantly reduce the environmental impacts associated with trichloroethylene, particularly when compared to the situation several years ago upon which the risk assessment is based (the latest literature search was undertaken in 1995).

In particular, the Solvent Emissions Directive is expected to cause a significant reduction in use and emissions of trichloroethylene in metal cleaning due to the requirement to phase out the substance where feasible and to impose limits upon emissions to atmosphere. The SED is due to be implemented by 2007.

Therefore, it is considered highly probable that compliance with the requirements of the Solvent Emissions Directive will be sufficient to adequately limit the risks to the environment.

In addition, the Integrated Pollution Prevention and Control regime is also required to be implemented by 2007 at the latest. This will impose (and is indeed currently imposing) additional controls on emissions, potentially including specific emission limits for trichloroethylene. Further information has been collated on emissions and local concentrations for specific sites and this is discussed in Appendix A. Conclusions are drawn in Section 5 on the effectiveness of IPPC in addressing the identified risks.

There is also a general trend away from the use of trichloroethylene. This is expected to be due to the revised classification and labelling (with consequences for other relevant legislation) and also the requirement to substitute trichloroethylene where practicable under the SED. The marketing and use restrictions for consumers also contribute to the reduction in use of the substance.

¹⁷ Judgement of the Court of 11 July 2000, *Kemikalienspektionen v Toolex Alpha AB*, Case C-473/98, European Court Reports 2000 Page I-05681.

Overall, these measures have had and will continue to have a significant effect in reducing the risks associated with the substance.

4. Possible Further Measures

4.1 Range of Available Measures and Screening

The Technical Guidance Document (European Commission, 1998) provides a range of different suggestions regarding measures that may be suitable for addressing various identified risks. Table 4.1 summarises the measures that could be used to control emissions of from manufacture and industrial use (measures that would not impact upon the identified risks are excluded).

Table 4.1 Summary of Possible Risk Reduction Measures Relevant for Trichloroethylene

Possible Measures	Comments on Applicability for Further Consideration
Restrictions on marketing and use under Directive 76/769/EEC	Could remove all risks associated with manufacture or use of trichloroethylene.
Re-design of the process or changing substances/materials used in it	Could potentially reduce risks but this measure would form part of an overall policy measure (e.g. permitting in relation to emissions limits).
Safe systems of work, such as specified standards of physical containment or extraction ventilation	Already required under carcinogens directive, SED, etc.
Classification and labelling	Classification already implemented and is already affecting use. Do not consider as a specific measure but ensure effects are taken into account in the baseline.
Monitoring and maintenance of equipment	Not considered to be directly relevant to addressing risks (which arise through the nature of the processes and equipment in place rather than the maintenance).
Licensing of operators or of certain operations	Producers, metal cleaners and users for production of other chemicals will already be licensed (under IPPC or SED). However, further controls could potentially be introduced through addition of specific requirements.
"End of pipe" controls to minimise, neutralise or render less harmful any emissions that cannot practically be avoided otherwise	Could be used to reduce emissions (and are already). Should be considered as part of regulatory requirements on emissions controls.
Limit values for emissions and effluent monitoring	Relevant emission limits included under e.g. SED. Potential for further targeting of emissions limits in relation to trichloroethylene.
Environmental quality standards and/or monitoring	Generally more applicable to wider environmental concentrations (rather than local concentrations that are of interest here). However, consideration will need to be given to meeting concentration limits which adequately address the risks.

Source: European Commission (1998).

In addition, there is a range of policy tools that could be used to implement the chosen risk reduction measures, including:

-
- Information programmes and other EC/Government initiatives;
 - Unilateral action by industry;
 - Voluntary agreements;
 - Technical standards and authoritative guidance;
 - Economic instruments;
 - Regulatory controls.

It was agreed by the steering group for this risk reduction strategy that the following four risk reduction options should be considered in detail:

- **‘Do nothing’** option, relying on current legislation and its continuing implementation over the next few years.
- **Emission limits or quality standards** introduced through legislation and/or official guidance for implementation of that legislation (Solvent Emissions Directive, Integrated Pollution Prevention and Control).
- **Marketing and use restrictions**, extending the existing restriction upon use in consumer products.
- **Voluntary emissions controls** as an alternative to a legislative approach.

In the remainder of this section, a brief background is provided as to how these measures could be implemented for the sectors of interest in this risk reduction strategy.

4.2 Description of Identified Measures

4.2.1 Do Nothing Option

There is good evidence that use of trichloroethylene is decreasing (Section 1) and also that emissions are decreasing (see Table 4.2 which presents emissions reported from large sites under the ‘pollution inventory’ in the UK). This is to be expected, given that there is a range of legislation that has been introduced in recent years relating to use and emissions of substances such as this.

Therefore, an analysis of the legislation that is currently being implemented could lead to the conclusion that the existing measures are sufficient to limit the risks (or that they will be when legislation is fully implemented).

Table 4.2 Reportable Air Emissions of trichloroethylene in England and Wales 1999-2003 (t)

1999	2001	2003
1,198	685	632

Source: Environment Agency (2004). Includes only sites reporting emissions of more than 1 tonne per year.

However, emissions of trichloroethylene have remained very significant within the EU in recent years. For example, sites reporting emissions for the European Pollutant Emissions Register emitted over 2,000 tonnes in 2001, as shown in Table 4.3.

Table 4.3 Emissions Reported to EPER for 2001 (tonnes)

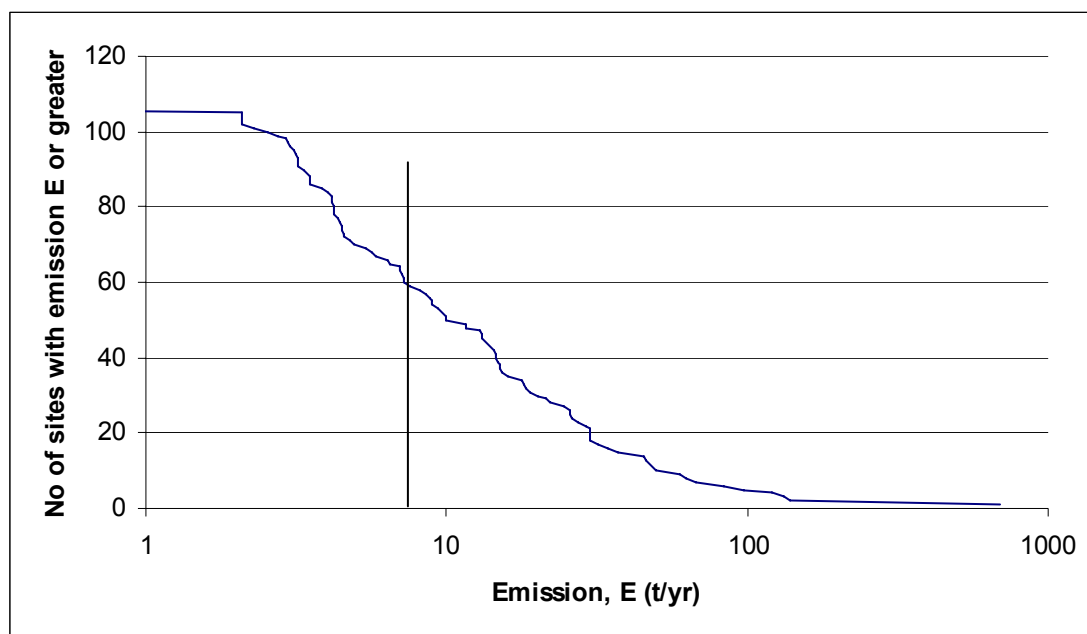
Country	Number of Sites	Emissions (t)
Finland	1	12
Sweden	1	9
Belgium	5	50
Spain	3	81
Italy	1	5
UK	24	413
Portugal	1	60
Denmark	1	3
France	69	2,071
Total	106	2,704

Source: EEA (2004).

It should be noted that the UK emissions for 2001 do not agree with those from the UK Pollution Inventory in Table 4.2. These data also exclude a large number of sites (perhaps indicating why the numbers for France and the UK are higher than for other countries). However, they are useful in providing an indication of the emissions currently occurring across the EU. These data should be used with caution given that the EEA (2004) has indicated that not all countries submitted full data sets and because there were problems reported with emissions estimation methodologies.

Based on the risk assessment (ECB, 2004) and equation 1 in Section 3, the quantity emitted which would lead to the conclusion that there is a need for limiting the risks would be approximately 23 kg/day (see Section 3.3.4). This corresponds to approximately 7 tonnes per year, assuming 300 days emission per year. As shown in Figure 4.1, there were a significant number of sites emitting more than this in 2001 (around 60 sites based only on those reporting to the EPER). However, this does not take into account reductions that may have been achieved at these sites between 2001 and the current time, as well as up to 2007 when the Solvent Emissions Directive must be fully implemented. Nor does it take into account the actual environmental concentrations (if dilution is sufficient, the PNEC may not be exceeded even if the emissions are greater than those for the realistic worst case site).

Figure 4.1 Number of Sites with Various Emissions in the EU 2001 (EEA, 2004)



4.2.2 Emission Limits or Quality Standards (legislative)

Further quantitative limits upon emissions from sites or on concentrations in the environment could potentially be introduced if the existing measures are not sufficient to limit the risks to an acceptable level.

Possible legislative means through which such controls could be introduced might include an amendment to existing legislation such as the Solvent Emissions Directive (which might also be extended to include the 'formulation' stage which is not covered by the SED and is not expected to be covered by other relevant existing legislation). Alternatively, limits could be specified in European and National guidance for processes regulated under the IPPC regime. Finally, specific legislation could be introduced in relation to trichloroethylene at the Community or national level.

4.2.3 Prohibition on Marketing and Use

As discussed in Section 3, marketing and use of trichloroethylene in consumer products has already been banned in the EU. If it represents the most appropriate balance of advantages and drawbacks, this could be further extended to prohibit some or all of the remaining uses, particularly use in metal cleaning and as an intermediate (less than 10% of historical use has been prohibited by the current marketing and use restrictions). This could be achieved under Directive 76/769/EEC. Since any prohibition would necessitate companies using substitutes, the analysis of this option should include analysis of the technical, economic and environmental/health implications of using substitutes.

It is noted that some members of the steering group for this project have concerns about the consideration of marketing and use restrictions for production of trichloroethylene and its use as an intermediate in production of other chemicals. However, it is important to consider a prohibition on these activities as it would be an effective means of addressing the environmental

risks. However, as detailed in Section 5, the analysis for this work suggests that a prohibition is not likely to be a cost-effective or proportional measure and it is not the preferred option.

4.2.4 Voluntary Emissions Controls

Voluntary action could be taken by the industry sectors concerned to ensure emissions from the relevant sectors are controlled to an acceptable level. The European Commission (2004) indicates three possible means by which such agreements may arise:

1. Purely spontaneous decisions initiated by stakeholders where the Commission has neither proposed legislation nor expressed an intention to do so;
2. A response by stakeholders to an expressed intention of the Commission to legislate; or
3. Agreements initiated by the Commission.

Whilst these agreements involve self-regulation (and hence are not legally binding) by relevant organisations, recognition may be given to such agreements by the Commission, as outlined in Table 4.4.

Table 4.4 Types of Environmental Agreement (European Commission, 2004)

Environmental Agreement	Description
Self-regulation	Encouragement/acknowledgement given by Commission where the Commission may stimulate the agreement an environmental agreement by means of an exchange of letters with the relevant industry's representatives or a Commission Recommendation. This could also involve a Parliament and Council Decision on monitoring of the agreement.
Co-regulation	<p>European Parliament and the Council Directive stipulating that a precise, well-defined environmental objective must be reached on a given target date, including conditions for monitoring compliance.</p> <p>This may also include a follow-up mechanism in case of failure to deliver the objectives (e.g. legislation).</p> <p>Where the Commission proposes co-regulation, it may include key elements based on existing or proposed voluntary agreements, which are satisfactory from the Commission's point of view. These may then be pursued in discussions with the other institutions.</p>

5. Assessment of Possible Further Measures

5.1 Overview of Assessment

This section provides an overview of the advantages and drawbacks of introducing possible further risk reduction measures on a sector-by-sector basis. It is based upon a combination of qualitative and quantitative data.

Section 5.2 provides a summary of the advantages and drawbacks of trichloroethylene itself. Section 5.3 details the availability and suitability of some potential substitutes for trichloroethylene in metal degreasing.

Sections 5.4 to 5.7 provide details of the analysis against a number of key decision criteria suggested in the Technical Guidance Document (European Commission, 1998), as well as a summary of the advantages and drawbacks of each possible measure for each of the life-cycle stages where a need for limiting the risks has been identified. These decision criteria are as follows:

- *Effectiveness* - Measures must be targeted at those significant hazardous effects and routes of exposure where risks that need to be limited have been identified by the risk assessment; and must be capable of reducing the risks within and over a reasonable period of time;
- *Practicality* - Measures should be implementable, enforceable and as simple as possible to manage (such that smaller enterprises are able to comply);
- *Economic impact* - This should include the impact of the measures on producers, processors, users and other parties; and
- *Monitorability* - Monitoring possibilities should be available to allow the success of the risk reduction to be assessed.

Appendix A provides a summary of some key information on each of the life cycle stages obtained from consultation with relevant industry representatives. This information should be referred to as appropriate when reading the following sections.

In undertaking consultation with the relevant industry sectors for this risk reduction strategy, information has been sought on current levels of emissions, as well as existing control techniques in place to limit the risks. This information is intended to provide a background on the current risk reduction measures in place for sectors where there are only a few sites, as well as a basis for estimating the technical and financial implications of different risk reduction measures. In no way does the information presented in this report bring in to question the

conclusions of the environmental risk assessment, which was based on a realistic worst case assessment of the risks using the data available at the time¹⁸.

5.2 Advantages and Drawbacks of Trichloroethylene

The key advantages of trichloroethylene relate to its technical properties in use, particularly in vapour degreasing of metals and as a feedstock for other chemicals. It is suggested that trichloroethylene and other chlorinated solvents are often the most effective method for cleaning metal components (ECSA, 2002). In economic terms, it is also often preferable to some other solvents, such as tetrachloroethylene.

The disadvantages of trichloroethylene, for the purposes of this risk reduction strategy, relate to its potential for adverse effects upon the environment and upon human health. Technical and economic disadvantages of the substance are not considered.

5.3 Potential Substitutes for use in Metal Degreasing

Since some of the possible measures under consideration - including the 'do nothing' option - would entail some replacement of trichloroethylene with substitute chemicals or alternative techniques, there is a need to consider the likely implications of these in financial, technical and risk terms. Consideration is given herein primarily to potential chemical replacements for trichloroethylene.

Appendix B provides a summary of some of the potential substitutes for trichloroethylene use in metal degreasing. These substances include tetrachloroethylene; n-propyl bromide; methylene chloride; and bromochloromethane. In addition, consideration is given in Appendix A to a number of other possible options for replacement of the substance, including aqueous cleaning and use of oils that can be removed by heating rather than by using a solvent.

Perchloroethylene is reported to be the most technically suitable substitute for trichloroethylene in the majority of cases, although this will depend upon the particular application. Methylene chloride also appears to be technically suitable for a number of applications, as evidenced by information from a number of companies that undertake metal degreasing (Appendix A).

Based on the information in Appendix B, it does not appear that any of the halogenated solvents would necessarily be more beneficial as compared to trichloroethylene in terms of effects upon the environment (e.g. the classification requirements for tetrachloroethylene indicate a potentially greater concern that trichloroethylene in relation to hazards for the aquatic environment). In terms of effects upon human health, there are some potential concerns with a number of the potential substitutes: bromopropane is a category 2 reproductive toxin¹⁹; both tetrachloroethylene and methylene chloride are category 3 carcinogens.

¹⁸ The risk assessment conclusions of interest state that "there is a need for limiting the risks; risk reduction measures which are already being applied shall be taken into account". Additional research undertaken for this risk reduction strategy is intended to address the latter point of this statement.

¹⁹ Bromopropane, classified as R60, will thus be subject to the same substitution requirement as trichloroethylene under the Solvent Emissions Directive and other relevant legislation (see Section 3).

It is of note that the environmental risk assessment for tetrachloroethylene did not reveal a need for limiting the risks associated with exposure of plants during use in metal degreasing whereas the assessment for trichloroethylene did. This is due to the minor differences in PNEC values for the substances and minor differences in the assumed quantities released.

On the basis of the information reviewed to date, it is not possible to clearly indicate that any of the potential substitutes will necessarily pose a significantly lower risk *in relation to the environmental endpoints considered in this risk reduction strategy* (notably effects upon plants via the atmosphere).

Under the Solvent Emissions Directive, the European Commission is required to publish guidance on the use of organic substances and their potential substitutes, including substances and techniques which have the least potential effects on air, water, soil, ecosystems and human health for each activity, following an exchange of information amongst Member States. The Commission has thus set up a website to provide guidance and an exchange of information²⁰.

In addition to other organic solvents, there exists the potential for substitution with various aqueous cleaning processes for some applications (they will not be suitable for all applications).

In the United Kingdom, various guidance and information has been published detailing the relative merits of different options for surface cleaning, including substitution. These include:

- Envirowise guidance on ‘surface cleaning and preparation - choosing the best option’ which states that *“an increasing number of alternatives [to trichloroethylene] are now available...However, these alternative solvents can also be hazardous to health, and without appropriate solvent management, a switch from trike to these solvents may simply expose operators to different dangers. The use of alternatives should be properly assessed, taking into account all considerations”* (Envirowise, 2002);
- A publication on suppliers of alternative substances for surface cleaning and other uses by the Engineering Employers Federation (EEF, 2002);
- An information sheet produced by the Health and Safety Executive (2002) giving basic advice to managers on proposed changes affecting health, safety and environmental controls on the use of trichloroethylene.

As indicated in the aforementioned Envirowise publication, there are a range of considerations that need to be taken into account in undertaking any substitution; indeed the industry commissioned its own study comparing the environmental impacts of trichloroethylene and aqueous solutions for degreasing of metallic parts. This concluded that:

“Aqueous technology is the best environmentally speaking to produce clean but wet metallic parts, thus solvent cleaning should not be used when an aqueous treatment is following the cleaning step (that is already the case and the best available technology (ACRU²¹) does not reach the level of the studied aqueous technology);”

²⁰ European Commission internet site, ‘Substitution of Solvents: Exchange of Information’ (http://europa.eu.int/comm/environment/air/solvents/index_en.htm), accessed February 2005.

²¹ Active carbon recovery unit.

“To produce clean and dry metallic parts, solvent technology is the best environmentally speaking, even without an activated carbon recovery unit; thus in cases where the metallic part needs to be dry for the following treatment (e.g. coating), a solvent cleaning should be used.” (ECSA, 1996)

Relevant guidance such as all of the publications mentioned above should be taken into account when considering substitution of trichloroethylene.

5.4 Production of Trichloroethylene

5.4.1 Do Nothing Option

In terms of *effectiveness*, whilst the do nothing option would not of itself sufficiently reduce the risks, regulation of the sites producing trichloroethylene under the IPPC regime may significantly reduce emissions to air as a result of the requirement to use the best available techniques in controlling emissions. Techniques identified for reducing emissions during production of VOCs such as trichloroethylene include adsorption, absorption, condensation, thermal oxidation, catalytic oxidation and biological techniques. Based on the information in Appendix A, it can be seen that thermal oxidation/incineration is already well used on at least two of the three EU production sites. Furthermore, it is evident that significant reductions in emissions have been achieved at these sites, particularly at the site that appears historically to have had the highest emissions.

It is possible, therefore, that existing legislation and its continuing implementation will be sufficient to reduce the risks to an acceptable level (given that the PEC/PNEC ratio is only 10).

There are no additional issues relating to *practicality* of implementation, nor for *economic impacts* for industry associated with the ‘do nothing’ option (since no additional actions are required). However, it would be appropriate to *monitor* the success of the continuing implementation of legislation and regulation in the Member States to ensure that risks to the environment are adequately limited.

5.4.2 Emission Limits or Quality Standards (under legislation)

All of the EU sites where production of trichloroethylene takes place are controlled under the Integrated Pollution Prevention and Control regime. As detailed in Section 3, although the Solvent Emissions Directive does not cover production of trichloroethylene, the relevant BREF Note for the large volume organic chemicals sector (European Commission, 2003) does refer to the emission limits set out in the Solvent Emissions Directive. It is likely that, if these emission limits were complied with, the need for limiting the risks would be eliminated. It is also possible, however, that a less stringent emission limit could ensure that the environmental risks are adequately controlled.

In terms of the *effectiveness* of this measure, therefore, specifying an emission limit to be complied with within the legally binding permits issued by the Member State Competent Authorities could be sufficient to effectively address the risks associated with this use.

The *practicality* of this measure is demonstrable through the existing means for Member States to introduce emission limit values under the Directive.

However, in terms of *economic impact*, the costs of implementation could vary significantly. For example, for one site identified, the capital costs of introducing an additional incinerator for certain vents where incineration does not already take place could be significant: approximately €60 million for one site alone, which is around half of the entire annual turnover associated with sales of trichloroethylene from *all* production sites. Even if this cost is borne over a period of a few years, it would still be expected to be a significant proportion of the site's annual turnover associated with this substance and could well be disproportionate in cost terms. Nonetheless, there could potentially be other means of achieving further emissions reductions at lower cost but these would need to be investigated between the regulator and the relevant company. It is also of note that one of the producers has indicated that a significant part of the emissions arises as a result of the need to maintain a positive pressure on the vent incinerator inlet. This requires positive pressure and a continuous bleed of small quantities of vent gas, which leads to emissions of 2-3% of the vent gases. This requirement is based upon the safety case for the site and the operator has indicated that a basis of safety could not be established for connection of all the vents because of concerns related to ingress of air into a fuel rich vent. Thus, the capital expenditure for this site would be significant and would relate to installing the aforementioned standby incinerator.

In specifying emission limits under the IPPC Directive and techniques to be used in the determination of what constitutes the best available techniques, a range of factors should be taken into account, including the costs and benefits of the measure. It could be appropriate, therefore, to ensure that regulators are fully aware of the conclusions of the environmental risk assessment and that this is taken into account in the determination of whether an emission limit value is appropriate.

It could be expected that *monitorability* of this measure would not be problematic, given that the sites are already regulated and are required to report emissions to the regulatory authorities.

5.4.3 Prohibition on Marketing and Use

A ban upon the marketing and use of trichloroethylene would be *effective* in reducing the risks associated with production, given that the risks associated with the substance would be eliminated. However, there would be risks introduced for the substitutes that would not necessarily be significantly lower than for trichloroethylene (this would depend upon the substances with which trichloroethylene would be replaced and the production sites, including increases in production at existing sites). Given the similarities in environmental risks with some possible alternatives (e.g. tetrachloroethylene) and the fact that emissions have already decreased significantly in recent years, the benefits of this measure are not likely to be very significant.

In terms of *practicality*, the implementation of marketing and use restrictions would be relatively simple, since the appropriate measures have been developed under Directive 76/769/EEC.

The *economic impact* of marketing and use restrictions for producers would be significant, with at least €100 million in turnover lost per year if all uses were banned. This could be a significant part of the turnover at each site and could potentially lead to losses in employment if alternative products could not be manufactured at the sites concerned. There would, however, be an increase in sales of substitutes which might offset the losses associated with trichloroethylene.

It is likely to be relatively simple to *monitor* this measure, given that there is only a limited number of current producers.

5.4.4 Voluntary Emissions Controls

Whilst introduction of voluntary emissions controls could potentially be as *effective* as introduction of emission controls through existing legislation (IPPC), in *practical* terms, it would be difficult to implement given that none of the three producers has expressed a willingness to sign up to voluntary controls and they have also suggested that such an approach would not be workable. Therefore, this approach is not considered further for production of the substance.

5.4.5 Summary of Advantages and Drawbacks

Table 5.1 provides a summary of the advantages and drawbacks of each of the options for production of trichloroethylene in the EU.

Table 5.1 Advantages and Drawbacks of Options - Production of Trichloroethylene

Option	Advantages	Drawbacks
Do nothing	<ul style="list-style-type: none"> • Would require no additional legislation. • Costs for affected sites would be limited. 	<ul style="list-style-type: none"> • Currently uncertain whether emissions are sufficiently controlled for all sites. • Lack of certainty on sufficiency of existing emissions reductions for all sites.
Emission limits/quality standards	<ul style="list-style-type: none"> • Existing regulatory regime under IPPC. • Gives regulatory certainty of reducing risks. • No increase in risks from substitutes. • Implementation through IPPC would enable BAT considerations at a site-specific level to avoid disproportionate costs. 	<ul style="list-style-type: none"> • Strict emission limits could pose excessive costs for some sites (e.g. €60m capital cost for one site). • Additional costs for regulatory actions related to enforcement.
Prohibition	<ul style="list-style-type: none"> • Removes risks for trichloroethylene. 	<ul style="list-style-type: none"> • Introduces risks for substitutes. • Loss of market of around €100m per year in the EU. • Downstream consequences in terms of product quality.
Voluntary emission controls	<ul style="list-style-type: none"> • Could potentially be as effective as regulatory emissions controls. 	<ul style="list-style-type: none"> • EU producers unwilling to sign up to voluntary agreement.

Based on the information available to date, it appears that there have been significant emissions reductions at some of the production sites. Therefore, it may be the case that emissions have already been limited sufficiently to remove the concern.

These sites are already regulated under the IPPC regime and, irrespective of whether existing legislation is considered to be sufficient, it would also be appropriate to ensure that the relevant regulators of affected processes are fully aware of the conclusions of the environmental risk assessment in order to determine whether there is any potential to further reduce emissions.

5.5 Formulation for Use as a Solvent

5.5.1 Do Nothing Option

As detailed in Appendix A, two *non-producers* have been identified that undertake formulation of trichloroethylene for use as a solvent in significant quantities. The total amount formulated by these companies is believed to be less than 5,000 tonnes per year, although the total amount handled (including, for example, loading into drums) is over two thirds of the total 32,500 tonnes of sales to non-feedstock uses in 2003.

One of these sites has emissions that are considerably lower than those considered for a realistic worst case site in the environmental risk assessment and would not, therefore, be expected to pose an unacceptable risk to the environment. The other site does not undertake monitoring of emissions; however, the amount formulated at the second site is relatively limited (although a larger amount if transfer into different sized vessels/tankers is taken into consideration).

Based on the information received to date, it cannot be ruled out that the processes concerned in formulation will have emissions that are high enough to pose an unacceptable risk to the environment. However, it is considered likely that the emissions will be small compared to those in the risk assessment (given that the majority of trichloroethylene throughput is simply transferred). It cannot, therefore, be concluded that this option would be *effective* in addressing the risks, particularly in the absence of data on emissions from all relevant sites.

There are no additional issues relating to *practicality* of implementation, nor for *economic impacts* for industry associated with the 'do nothing' option (since no additional actions are required). If this option were to be preferred, work would need to be undertaken to monitor the current levels of emissions and whether an unacceptable risk to the environment could be ruled out.

5.5.2 Emission Limits or Quality Standards (under legislation)

As with production sites, introduction of emission limits for sites undertaking formulation could be very *effective* in addressing the environmental risks. No new risks associated with possible substitutes would be introduced (except if companies decided to formulate alternative solvents rather than comply with emissions requirements).

In terms of *practicality*, however, formulation of chemicals is not currently covered under EU pollution control legislation such as the Solvent Emissions Directive or the IPPC Directive in terms of emissions to air. It would be necessary, therefore, to introduce additional requirements under such legislation to encompass formulation of substances for use as solvents. For example, under the Solvent Emissions Directive, manufacture (formulation) of coatings and adhesives is already covered and, like the formulation process considered here, it does not involve end-use of the substance. However, it is expected that the Solvent Emissions Directive is likely to be considered an inappropriate means for introducing controls on this issue given that it would be administratively problematic to add an extra activity to the Directive, particularly for a single-substance issue such as this (rather than a generic issue related to volatile organic compounds).

However, since there are established pollution control regimes in the Member States, emission limits for these installations could potentially be introduced through country-level action, perhaps under a Recommendation from the European Commission.

The *economic impact* of this measure would depend upon what, if any, emissions reductions would be required. If emissions abatement equipment were required in order to reduce emissions, the annualised cost of this equipment might be expected to be somewhere between around €45,000-€345,000 for a single site for catalytic oxidation of emissions or around €15,000 to €30,000 for carbon adsorption. The cost for modifications to road tankers and storage tanks could be around €33,500 (see Appendix A). There could also be savings of up to €44,000 per 10,000t of trichloroethylene handled, although the savings in practice would probably be substantially lower than this and would be dependent on site-specific conditions.

It would be important to ensure that there are adequate provisions for *monitoring* the success of any emission limits, either through existing regulatory regimes or any new legislative requirements in the Member States. If this is done through existing regimes, it is expected that the success of this option could be monitored relatively easily.

5.5.3 Prohibition on Marketing and Use

Prohibition of this life cycle stage would be an *effective* measure in terms of reducing the risks associated with trichloroethylene. However, it would require companies to use an alternative solvent or process which would not necessarily have lower risks as compared to trichloroethylene. Alternatively, it would require this activity to be undertaken at production facilities, rather than at separate sites.

In terms of *practicality*, the implementation of marketing and use restrictions would be relatively simple, since the appropriate measures have been developed under Directive 76/769/EEC. However, this option is not considered to be an appropriate measure for this life-cycle stage, given that the activity can be carried out without unacceptable risks to the environment.

The *economic impact* of this measure is difficult to quantify for this sector. The value of sales lost would be a proportion of total trichloroethylene sales which are estimated to be worth around €100 million per year²². It could also potentially impose costs associated with reduced efficiency of distribution.

It is likely to be relatively simple to *monitor* this measure, given that there is only a limited number of companies that will undertake this practice. However, these companies would need to be identified. Monitoring the handling of imported trichloroethylene might also be problematic.

5.5.4 Voluntary Emissions Controls

Whilst introduction of voluntary emissions controls could potentially be as *effective* as introduction of emission controls through existing legislation (IPPC), in *practical* terms, it would be difficult to implement. The two companies identified for this risk reduction strategy have indicated that they would not contemplate any further voluntary actions at present. Therefore, this approach is not considered further in relation to formulation for use as a solvent.

²² This includes approximately 30,000 tonnes sold for use mainly in metal degreasing and around 65,000 tonnes used as an intermediate. The price of trichloroethylene is assumed to be €1100 per tonne. This is described further in Section 1. Only trichloroethylene sold for metal degreasing and other minor uses would be affected.

5.5.5 Summary of Advantages and Drawbacks

Table 5.2 provides a summary of the advantages and drawbacks of each of the options for formulation of trichloroethylene for use as a solvent.

Table 5.2 Advantages and Drawbacks of Options - Formulation for Solvent Use

Option	Advantages	Drawbacks
Do nothing	<ul style="list-style-type: none"> • Would require no additional legislation. • Costs for affected sites would be limited. • Some sites expected to be compliant already. 	<ul style="list-style-type: none"> • Lack of certainty regarding emissions given limited monitoring.
Emission limits/quality standards	<ul style="list-style-type: none"> • Gives regulatory certainty of reducing risks. • No increase in risks from substitutes. 	<ul style="list-style-type: none"> • Not currently controlled under relevant legislation (IPPC, SED) and would be difficult to add this process specifically. • Costs of compliance could be high. • Additional costs for regulatory actions related to enforcement.
Prohibition	<ul style="list-style-type: none"> • Removes risks for trichloroethylene. 	<ul style="list-style-type: none"> • Potentially introduces risks for substitutes. • Loss of market of a fraction of the €100m per year value of sales in the EU. • Downstream consequences in terms of product quality of metal products.
Voluntary emission controls	<ul style="list-style-type: none"> • Could potentially be as effective as regulatory emissions controls. 	<ul style="list-style-type: none"> • Companies identified for this work are unwilling to participate.

As discussed above, existing information on the sites in question is not sufficient to eliminate the concerns identified in the risk assessment, given the lack of available monitoring data. Therefore, the 'do nothing' option is not considered appropriate.

Voluntary emissions controls are not considered to be appropriate given the apparent lack of willingness amongst the companies involved. The cost of marketing and use restrictions is likely to be significant and disproportionate, although the operations in question could presumably be undertaken at existing production sites as an alternative to being undertaken at separate premises. Marketing and use restrictions for this intermediate life-cycle stage are not considered to be proportionate or appropriate, particularly given that the activity can and is carried out at sites with minimal releases to the environment.

It is considered that the most appropriate option for this sector is likely to be as follows:

- For emissions monitoring to be required/undertaken in order to determine whether emissions from these sites are sufficient to pose concerns equivalent to those identified in the risk assessment. This need only be undertaken for the largest sites (e.g. handling over around 7,000 tonnes per year), given that smaller sites would be unlikely to pose an unacceptable risk to the environment based on the default emission factors used in the environmental risk assessment;
- If, following this monitoring, emissions are found to be sufficient to cause a concern for risks to the environment, it could be appropriate for legally binding

limits on emissions to be introduced by the Member States (perhaps under a Recommendation from the Commission). These limits could be regulated under the existing regimes established for air pollution control in the Member States.

Since this activity falls outside the scope of the IPPC Directive, Member States would need to implement national legislation through their own existing regimes for pollution control at smaller sites or those that are not covered by IPPC (or other appropriate regimes). These regimes are frequently concerned specifically with emissions to air²³.

It is considered that Community level legislation on emissions control is unlikely to be appropriate for this sector, given that the number of sites handling large quantities of trichloroethylene is low²⁴ and that many processes will already be well controlled.

5.6 Metal Degreasing

5.6.1 Do Nothing Option

Detailed consideration has been given to the *effectiveness* of the Solvent Emissions Directive in achieving emissions reductions from metal degreasing. As detailed in Section 3 of this report, the Directive introduces much more stringent requirements for emissions control than were assumed in the environmental risk assessment. The options for compliance are as follows:

- Reduce solvent consumption to below 1 t/yr to fall outside the scope of the Directive. Where companies choose this route, it is considered that the risks would be adequately limited, given that a consumption of 20 t/yr assumed in the risk assessment only led to a risk characterisation ratio of 1.5 using worst case assumptions regarding releases;
- Substitute trichloroethylene within the “shortest possible time”. Where companies choose this route, the need for limiting the risks associated with trichloroethylene would be eliminated. However, new risks associated with any substitutes could be introduced; or
- Achieve an emission limit value of 2 mg/Nm³ (or 20 mg/Nm³ where the mass flow is less than 10g/h). Based on consultation undertaken for this risk reduction strategy, companies will need to use closed type machines in order to meet this emission limit value, or significantly reduce their consumption. Since both of these methods are considered sufficient to reduce the PEC value significantly, the emissions reductions achieved are expected to be sufficient to adequately reduce the risks.

Therefore, it is considered highly probable that compliance with the requirements of the Solvent Emissions Directive will be sufficient to adequately limit the risks to the environment.

²³ Such as the Local Authority Pollution and Prevention and Control regime for ‘Part B’ processes in the UK; BImSchG/TA Luft in Germany; installations Classées regulations in France; and the Dutch Emission Guidelines for Air, NER.

²⁴ Only those handling several thousands of tonnes per year could be expected to pose a risk to the environment, based on the conclusions of the risk assessment.

Whilst there are issues associated with the *practicality* of implementing the Solvent Emissions Directive, these are not associated with this risk reduction strategy and so are not considered herein. Consideration has already been given in the UK to implementation of the Solvent Emissions Directive²⁵, in which the costs for surface cleaning using solvents were estimated to form the greatest part of the compliance costs. There would be no additional *economic impacts* for industry associated with the 'do nothing' option (since no additional actions are required). However, it would be appropriate to *monitor* the success of the continuing implementation of legislation and regulation in the Member States to ensure that risks to the environment are adequately limited.

Where companies do not comply with the requirements of the Solvent Emissions Directive, this is considered to be a matter for the relevant enforcing authorities under that Directive, rather than an issue to be addressed in this risk reduction strategy. However, it would be worthwhile assessing the extent to which any companies are achieving compliance with the Solvent Emissions Directive over time (i.e. up to the final implementation deadline of 2007).

5.6.2 Emission Limits or Quality Standards (under legislation)

Emission limits are not considered further for metal degreasing because limits are already in place and these are considered sufficient to ensure that the emissions are adequately addressed.

5.6.3 Prohibition on Marketing and Use

A prohibition on marketing and use would require the use of alternative solvents or techniques. It would be *effective* in reducing the risks associated with trichloroethylene but could lead to increased risks associated with the use of substitutes. Since there is a requirement under the Solvent Emissions Directive to substitute trichloroethylene (subject to certain caveats regarding technical and economic feasibility), such substitution will be taking place in any case. Given that emissions will have to be strictly controlled where trichloroethylene is not substituted, it is possible that the overall level of risk could be increased by a ban upon use in this application: companies could choose to use a substance that is not significantly better in risk terms and may not be subject to the same requirements upon emissions. Therefore, it cannot be concluded that this measure would necessarily be effective - *above existing legislation* - in reducing the overall level of risk.

Whilst it would be relatively *practicable* to implement such as restriction, the *economic impacts* could be highly significant: this would remove the choice from companies as to how they achieve compliance with the Solvent Emissions Directive and could be expected to remove the least cost option in some cases. All options for compliance with the Directive are expected to adequately address the environmental risks associated with trichloroethylene to an acceptable level.

As detailed in Appendix A, trichloroethylene is considered to be the most effective solvent in certain applications (e.g. metal tubes). There could be cost implications in terms of decreased downstream product quality if the alternatives do not perform adequately. Similarly, there

²⁵ <http://www.defra.gov.uk/corporate/consult/solvemissions/>.

would be costs associated with the need to renegotiate any contracts where it is specified that trichloroethylene must be used (e.g. in medical equipment or in aircraft²⁶).

There could potentially be some issues regarding *monitoring* the success of such an instrument if trichloroethylene were to be sold to metal cleaners illegally. This would also be a possible concern in relation to imports from outside the EU.

At the first steering group meeting for this project, it was suggested that consideration be given to the potential for specifying that trichloroethylene only be used in enclosed systems for metal degreasing. Based on the discussion in the preceding sections, it is concluded that there is no other means for companies to comply with the Directive than by using equipment that would be sufficient to limit the risks adequately. Therefore, this has not been addressed in more detail.

5.6.4 Voluntary Emissions Controls

Given the large number of companies undertaking metal cleaning (several thousand in the UK alone) and the existing legislative emissions controls under the Solvent Emissions Directive, voluntary emissions controls are not considered further.

5.6.5 Summary of Advantages and Drawbacks

Table 5.3 provides a summary of the advantages and drawbacks of each of the options for use of trichloroethylene in metal degreasing.

Table 5.3 Advantages and Drawbacks of Options - Use in Metal Degreasing

Option	Advantages	Drawbacks
Do nothing	<ul style="list-style-type: none"> Considered that existing controls under SED are sufficient to limit the risks (by 2007 compliance date). No additional costs for industry or authorities. 	<ul style="list-style-type: none"> Potential for non-compliance with SED but this is outside the remit of this risk reduction strategy.
Emission limits/quality standards	<ul style="list-style-type: none"> Already introduced so not considered further here. 	<ul style="list-style-type: none"> Already introduced so not considered further here.
Prohibition	<ul style="list-style-type: none"> Would effectively reduce the risks for trichloroethylene. 	<ul style="list-style-type: none"> Risks for substitutes could be greater and emissions controls less stringent since it removes other options for SED compliance. Additional costs above and beyond already significant costs under SED. Potential significant downstream costs and product quality issues where trichloroethylene considered 'essential' at present.

²⁶ In the UK, trichloroethylene is reported to be specified in certain contracts with the Ministry of Defence. There are understood to be other requirements elsewhere in the EU that specify the use of trichloroethylene in degreasing of products.

Option	Advantages	Drawbacks
Voluntary emission controls	<ul style="list-style-type: none"> • Not considered. 	<ul style="list-style-type: none"> • Not considered.

Based on the information presented in this report, it is considered that existing controls - the Solvent Emissions Directive in particular - are sufficient to adequately limit the risks for this application (when fully implemented by 2007). At the steering group meeting on 20 January 2005, members of the group agreed with this position.

5.7 Use as an Intermediate

5.7.1 Do Nothing Option

Information has been made available by companies using the majority of the 65,000 tonnes trichloroethylene that is used as an intermediate (feedstock) in the European Union each year. Based on the information presented in Appendix A, it appears that, in practice, emissions are likely to be significantly lower than those assumed in the risk assessment at the majority of sites.

However, given that monitoring of emissions or relevant concentrations is not undertaken for all sites, it is not currently possible to determine whether the 'do nothing' option would ensure that the potential risks are adequately addressed at all sites.

5.7.2 Emission Limits or Quality Standards (under legislation)

As with production of trichloroethylene, introduction of emission limit values under the IPPC regime which take into account the conclusions of the environmental risk assessment could be *effective* in ensuring that the risks are adequately controlled. Similarly, this would be *practicable* to implement, given that there is an existing regime for implementation of emission limits and a relatively small number of sites involved.

For most of the companies involved, it is envisaged that the economic impacts would be limited to a requirement to determine and communicate emissions of trichloroethylene to the regulatory authorities where this is not already undertaken (in the majority of cases this will already be done).

For any sites where the emissions and/or concentrations of trichloroethylene exceeded any the levels at which an unacceptable risk could occur, there would be a need to consider the potential for further emissions controls, using the best available techniques²⁷.

Potential techniques that could be used to reduce emissions of VOCs such as trichloroethylene are similar to those for production. Table 5.4 provides a summary of some of the available techniques based on the BREF Note for the large volume organic chemicals sector (European

²⁷ This would include consideration of whether techniques could be adopted under economically and technically viable conditions, taking into consideration the costs and advantages (as specified in the IPPC Directive).

Commission, 2003). It is considered that all of these techniques would be sufficient to reduce the emissions to an acceptable level as compared to the realistic worst-case site included in the risk assessment, because the calculated PEC/PNEC ratio is only 2.5 (the abatement efficiency of all of these techniques is at least 95%).

Table 5.4 Possible Techniques for Reducing Emissions in Use as an Intermediate

Technique	CAPEX (€k)	Total Annualised Cost (€k)
Incineration without energy recovery	733	682
Incineration with 70% energy recovery	876	356
Incineration with thermal regeneration	1077	263
Catalytic incineration	942	301
Adsorption	2168	471 ^[1]

Converted from £1999 to €2004 using a factor of 1.068 based on the UK consumer price index and an exchange rate of €1.4 per £.

[1] Does not include benefit of recovered VOCs.

Source: European Commission (2003).

Thus, the annualised cost of, for example, installation of incineration with energy recovery could be around €350k per site. This would be the maximum expected costs, however, given that other potential changes could ensure that the PEC/PNEC ratio is reduced by a factor of 2.5. Furthermore, if no additional abatement were deemed to be required, the only costs would be for demonstrating compliance with an appropriate emission limit value.

Monitoring the success of controlling emissions would not be expected to be problematic, given that there are procedures in place for introducing and monitoring compliance with emission limits under the IPPC regime.

5.7.3 Prohibition on Marketing and Use

A ban upon the use of trichloroethylene would be *effective* in addressing the risks identified in this risk assessment. However, whilst there are other potential routes to synthesis of chemicals that are produced using trichloroethylene (e.g. HFC-134a), the companies concerned do not consider these appropriate for the sites in question.

In terms of *practicality*, the implementation of marketing and use restrictions would be relatively simple, since the appropriate measures have been developed under Directive 76/769/EEC.

The *economic impact* of marketing and use restrictions for use as an intermediate could be very significant. HFC-134a (which is thought to be the main substance produced) is used extensively in air conditioning units, such as those in motor vehicles. There is already a European Commission proposal (European Commission, 2003a) to phase out the use of HFC-134a in new mobile air conditioning systems (as well as to introduce minimum leakage and containment requirements as well as recovery requirements). The annualised costs of this restriction have

been estimated for the UK as between £33.8 million and £173.9 million (around €47m to €240m per year) (Defra, 2003b).

It is likely to be relatively simple to *monitor* this measure, given that there are only a limited number of companies using trichloroethylene as an intermediate in significant quantities. All of these sites will be controlled under the IPPC regime, providing a means of contact for the regulators.

5.7.4 Voluntary Emissions Controls

Two of the companies with EU-based sites have indicated that they believe that legislation or guidance on emission limits or quality standards is the most appropriate option (with appropriate consultation between industry and government). None of the EU-based sites have indicated that voluntary action would be considered the most appropriate.

Therefore, whilst voluntary controls would potentially be less costly than legislation, this approach for this sector is not considered to be a practical option.

5.7.5 Summary of Advantages and Drawbacks

Table 5.5 provides a summary of the advantages and drawbacks of each of the options for use of trichloroethylene as an intermediate.

Table 5.5 Advantages and Drawbacks of Options - Use as an Intermediate

Option	Advantages	Drawbacks
Do nothing	<ul style="list-style-type: none"> Costs would be minimal/negligible. 	<ul style="list-style-type: none"> Uncertainty whether emissions would be reduced at all sites and potential risks for the environment.
Emission limits/quality standards	<ul style="list-style-type: none"> Could effectively control risks. Existing legislative regime (IPPC) 	<ul style="list-style-type: none"> Potentially high costs (e.g. €350k per site annualised cost for incineration) which is likely to be excessive given the relatively low PEC/PNEC ratio. However, costs could be minimal given that information available to date suggests little additional emission reduction would be required. Additional costs for regulatory actions related to enforcement.
Prohibition	<ul style="list-style-type: none"> Would effectively address the risks for trichloroethylene. 	<ul style="list-style-type: none"> No other commercially used routes identified for HFC-134a production at the sites in question. Potential downstream costs (e.g. air conditioning) if HFC-134a cannot be used or is more expensive. Potential risks associated with substitutes.
Voluntary emission controls	<ul style="list-style-type: none"> Would potentially be less costly than legislation. 	<ul style="list-style-type: none"> Unlikely to be viable in terms of gaining co-operation from all companies involved.

Based on the analysis undertaken for this risk reduction strategy, it is considered that the most appropriate option would be to ensure appropriate emission limits for trichloroethylene from sites using trichloroethylene as an intermediate in production of other chemicals. The most appropriate means of doing this would be under the Integrated Pollution Prevention and Control regime. Appropriate emission limit values could be developed based on the conclusions of the risk assessment, taking into account practical considerations appropriate to the category of installation.

The ‘do nothing’ option is not considered appropriate, given that information on current levels of emissions is incomplete: it does not, therefore, provide a means of ensuring that the risks are adequately limited and a means of monitoring this. A prohibition on use of trichloroethylene in this application is considered to be inappropriate and disproportionate, given the significant costs involved, both for producers who would lose a significant market (likely to be worth several tens of millions of Euros per year), potentially to companies from outside the EU. There would also be significant downstream costs in terms of replacement of HFC-134a in air conditioning in particular.

Voluntary emission controls are not considered appropriate given that it is likely to be difficult to ensure that all of the companies involved will sign up to such an agreement (companies contacted indicated that emission limits are considered the most appropriate means of controlling emissions).

5.8 Recycling of Trichloroethylene

Whilst no need for limiting the risks was identified for sites undertaking recycling of trichloroethylene, given the relatively large quantities recycled in the EU and the potential for emissions from these sites, it would also be appropriate for regulators under the IPPC regime to be made aware of the conclusions of the environmental risk assessment and to be given guidance on how to take this into account in setting emission limit values for these sites.

There would be costs for the regulators associated with incorporating these requirements into their existing regulation and enforcement roles.

6. Conclusions and Recommendations

6.1 Conclusions

6.1.1 Uses and Environmental Risks of Trichloroethylene

Usage of trichloroethylene for applications other than as a feedstock in production of other chemicals has declined significantly over recent years, with sales in 2004 estimated at 32,500 tonnes. The main application is in metal degreasing, with a minor additional consumption in adhesives and other applications. In addition to that, use as a feedstock (mainly in production of HFC-134a) represents around 65,000 tonnes per year. Total sales are estimated to be worth in the order of €100 million per year.

The environmental risk assessment identified a need for limiting the risks to plants associated with the following life-cycle stages:

- Production of trichloroethylene (PEC/PNEC ratio = 10);
- Use as an intermediate in production of other chemicals (2.5);
- During handling/formulation for use as a solvent (14); and
- In metal degreasing (1.5).

In addition, a need for limiting the risks for humans via the environment was identified, related to carcinogenicity and mutagenicity endpoints, since there is no identifiable threshold exposure for these effects. However, the risk assessment concluded that the environmental exposures, and hence the risks, are likely to be very low (and several orders of magnitude lower than potential workplace exposure). Therefore, the key driver for this environmental risk reduction strategy is considered to be the conclusions in relation to environmental exposure and the risk of harm to plants, rather than for humans exposed via the environment.

A human health risk reduction strategy is also being developed. This is expected to include recommendations for introducing an EU harmonised occupational exposure limit to help define adequate control; development of statements of best practice for control of exposure; and adoption of an industry standard for biological monitoring between the relevant industry sectors involved.

6.1.2 Current Risk Reduction Measures

A range of existing risk reduction measures have been considered, including:

- A prohibition on sales of trichloroethylene to consumers;
- Control of air emissions under the IPPC regime (applies to trichloroethylene production, use as an intermediate and some metal degreasing operations);
- The solvent emissions directive, which applies to metal degreasing where trichloroethylene consumption is greater than 1 tonne per year. This will require

substitution of trichloroethylene, compliance with a strict emission limit, or a reduction in consumption which would likely preclude unacceptable risks to the environment;

- The revised classification and labelling of trichloroethylene which requires substitution or enclosure of trichloroethylene processes where possible (under legislation such as the carcinogens directive);
- Emission limits and quality standards for water; and
- Workplace concentration limits.

It is considered highly probable that compliance with the requirements of the Solvent Emissions Directive will be sufficient to adequately limit the risks to the environment in relation to metal degreasing. This conclusion was agreed with the members of the steering group at a meeting in January 2005.

In addition, the Integrated Pollution Prevention and Control regime will impose (and is indeed currently imposing) additional controls on emissions, potentially including specific emission limits for trichloroethylene. Current emissions at production sites and those using trichloroethylene as an intermediate suggest that the risks at most sites are likely to be adequately controlled.

There is also a general trend away from the use of trichloroethylene. This is believed to be due to the revised classification and labelling of trichloroethylene (with consequences for other relevant legislation) and also the requirement to substitute trichloroethylene where practicable under the SED. The marketing and use restrictions for consumers also contribute to the reduction in use of the substance.

Overall, these measures have had and will continue to have a significant effect in reducing the environmental risks associated with the substance.

6.1.3 Assessment of Possible Further Measures

It was agreed by the steering group for this risk reduction strategy that the following four risk reduction options should be considered in detail:

- ‘Do nothing’ option, relying on current legislation and its continuing implementation over the next few years.
- Emission limits or quality standards introduced through legislation and/or official guidance for implementation of that legislation (Solvent Emissions Directive, Integrated Pollution Prevention and Control).
- Marketing and use restrictions, extending the existing restriction upon use in consumer products.
- Voluntary emissions controls as an alternative to a legislative approach.

These options have been considered for each of the sectors where a need for limiting the risks has been identified. The relative advantages and drawbacks of these measures has been considered, based on a range of criteria set out in the Technical Guidance Document on Development of Risk Reduction Strategies.

For **production of trichloroethylene**, information has been provided by all of the EU-based producers on current emissions, and environmental concentrations in one case. By comparison to the results of the risk assessment, it is considered likely that there have been significant reductions in emissions at some of the production sites. Therefore, it may be the case that emissions have already been limited sufficiently to remove the concern. However, emissions data would, of course, need to be properly verified.

These sites are already regulated under the IPPC regime and, irrespective of whether existing legislation is considered to be sufficient, it would also be appropriate to ensure that the relevant regulators of affected processes are fully aware of the conclusions of the environmental risk assessment in order to determine whether there is any potential to further reduce emissions, as well as to ensure that emissions are well controlled.

In **formulation for use as a solvent** (which is also taken to include repackaging/drum filling), information has been received from two non-producer companies that, between them, are believed to supply over two thirds of trichloroethylene used in non-feedstock applications in the EU. However, only a relatively small quantity of trichloroethylene actually undergoes 'formulation', with the remainder simply stored and repackaged for supply.

Formulation of trichloroethylene is not currently directly regulated under any Community pollution control regimes. There appear to be differences between the companies in terms of the level of controls on emissions and on whether emissions monitoring or estimation is undertaken.

The 'do nothing' option and that for voluntary emission controls are not considered to be sufficiently effective or practical for this use. The costs of marketing and use restrictions are considered to be disproportionate (although the operations in question could presumably be undertaken at existing production sites as an alternative to being undertaken at separate premises).

Since there remains uncertainty regarding whether emissions from these sites will actually pose an unacceptable risk for the environment, it is considered that the most appropriate option for this sector is likely to be as follows:

- For emissions monitoring to be required/undertaken in order to determine whether emissions from these sites are sufficient to pose concerns equivalent to those identified in the risk assessment (i.e. PEC/PNEC ratio >1). This need only be undertaken for the largest sites (e.g. handling over around 7,000 tonnes per year), given that smaller sites would be unlikely to pose an unacceptable risk to the environment based on the default worst-case emission factors used in the environmental risk assessment. Therefore, the costs of undertaking this monitoring would be expected to be moderate;
- If, following this monitoring, emissions are found to be sufficient to cause a concern for risks to the environment, it could be appropriate for legally binding limits on emissions to be introduced by the Member States (perhaps under a recommendation from the Commission). These limits could be regulated under the existing regimes established for air pollution control in the Member States.

For **metal degreasing**, it is considered that existing controls - the Solvent Emissions Directive in particular - are sufficient to adequately limit the risks for this application (when fully implemented by 2007). At the steering group meeting on 20 January 2005, members of the group agreed with this position.

In relation to **use as an intermediate**, the situation is similar to that for production sites: it is likely that, in general, emissions are currently lower than those considered in the risk assessment. However, emissions data were not available for all sites.

As with production sites, these sites are already regulated under the IPPC regime and it would be appropriate to ensure that the relevant regulators of affected processes are fully aware of the conclusions of the environmental risk assessment in order to determine whether there is any potential to further reduce emissions, as well as to ensure that emissions are well controlled.

6.1.4 Conclusions on the Most Appropriate Risk Reduction Strategy

For sites producing trichloroethylene and using the substance as an intermediate in the production of other chemicals, it is concluded that the most appropriate action would be to ensure that regulators under the IPPC regime take into account the conclusions of the environmental risk assessment in developing emission limits for sites. This should include consideration of whether techniques could be adopted under economically and technically viable conditions, taking into consideration the costs and advantages on a site-specific basis. It is also considered appropriate to apply the same approach for companies recycling trichloroethylene where covered by the IPPC regime.

For metal degreasing, it is concluded that there is likely to be no need for further risk reduction measures once the requirements of the Solvent Emissions Directive are fully implemented, by 2007.

In relation to sites undertaking 'formulation' or repackaging of trichloroethylene in significant quantities, it is concluded that there is insufficient information to determine whether existing risk reduction measures are sufficient. Therefore, it is concluded that the most appropriate strategy would be to:

- a) Require that emissions monitoring be undertaken for the largest sites undertaking this activity (smaller sites are not expected to pose unacceptable environmental risks). This should be demonstrated to the satisfaction of the Commission or Member States, as appropriate.
- b) For the Member States to introduce legally binding limits on emissions if current emissions are still found to pose an unacceptable risk to the environment. This requirement could perhaps be introduced under a Recommendation from the Commission.

It is considered that Community level legislation on emissions control is unlikely to be appropriate for this sector, given that the number of sites handling large quantities of trichloroethylene is low and that many processes will already be well controlled.

These conclusions were agreed at a meeting of the steering group for this risk reduction strategy on 2 March 2005.

6.2 Recommendations

It is recommended that the conclusions of this report are taken into account by the UK Government and the European Commission in determining the most appropriate strategy to address the environmental risks associated with trichloroethylene in the European Union.

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Appendix A

Background Information on Sectors

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A1. Production of Trichloroethylene

A1.1 Summary of Consultation

For the purposes of this risk reduction strategy, all of the EU-based producers of trichloroethylene have been consulted in relation to the quantities of the substance produced; current emissions controls and potential for further reductions; and views on the most appropriate risk reduction strategy for this stage in the life-cycle. This consultation was undertaken by dissemination of a questionnaire to each of the companies involved.

All of the companies consulted are considered to be 'large' companies, with greater than 250 employees and an annual turnover greater than €50 million.

Annual production from these sites is roughly 120,000 tonnes, as compared to EU sales of around 95,000 tonnes (see Section 1 of the main report). Therefore, there is expected to be a net export of the substance to outside the EU.

A1.2 Current Controls and Potential for Further Emission Reductions

Table A1.1 summarises the emissions controls and current emissions at each of the three sites for which information was provided for the purposes of this study.

Table A1.1 Estimated Emissions at EU Production Sites

Site	Emissions Controls	Emissions
P1	To be confirmed	36 tonnes in 2002.
P2	Refrigeration of vent gases from main vents on reactor. Residual vent gases incinerated (with recovery of energy and HCl).	Emissions in 2003 were 154t compared to over 850t in 2000. Bleed vent for safety reasons typically loses 2-3%, although may be higher if incinerator is not available. Boundary fence and measurements in the community around the site indicate average levels less than 1 ppb (5.4 µg/m ³).
P3	Waste gas collection and incineration system with energy and HCl recycling.	No emissions recorded in vent gases. Concentrations not detectable at site boundary.

The emissions detailed in Table A1.1 can be compared to those considered in the risk assessment in which the largest release reported from a production site was 879 tonnes per year. Site specific data from this site indicated that the average concentration measured at the site boundary was 65 µg/m³, the value that was used as the PEC in the risk characterisation. Based on this information, it may be the case that the current levels of emissions may not pose an unacceptable risk to the environment. It is proposed that this be investigated in co-operation with the Environment Agency during Stage 3 of the risk reduction strategy.

In relation to downstream users, one of the companies has indicated that they favour solvent transfer from and to equipment using e.g. closed loop systems with vapour return lines or a solvent abatement system. This would reduce emission losses during transfer and is required under German legislation.

Based on the views of the companies concerned, the primary means of achieving further emissions reductions in the production would be to undertake incineration/oxidation of vent gases or to increase existing incineration capacity to deal with emissions streams that are not currently captured (or may not be fully captured). Where emissions are reportedly not detectable, obviously no additional techniques would be appropriate.

The two sites where potential for further emissions reductions has been identified have identified the following additional costs:

- For connection to an existing incinerator – assumed to be for another facility at the same site – the cost has been estimated as €3 million for the connection, plus part of the cost of the thermal oxidiser;
- A capital cost of around €56 million and annual operating costs of around €1.4 million for installation of a standby incinerator to capture emissions resulting during downtime of the existing incinerator for vents and potentially to capture emissions from the bleed vent system.

Thus, for the two sites where potential for further emissions reductions has been identified, the additional capital costs of installing further incineration would be around €59 million, with additional operating costs of around €2 million per year. This equates to an annualised cost of around €15 million, assuming repayment over a period of five years and a discount rate of 3.5%.

As detailed in the main part of this report, the identified concern in relation to emissions from production was based on site-specific data. Data in Table A1.1 indicate that there appears to have been a significant reduction in emissions from production sites in recent years. This could potentially negate the need for any further risk reduction measures, although the PEC/PNEC ratios have not been re-calculated for the purposes of this risk reduction strategy.

One of the producers has indicated that a significant part of the emissions arises as a result of the need to maintain a positive pressure on the vent incinerator inlet, requiring positive pressure and a continuous bleed of small quantities of vent gas and hence leading to emissions of 2-3% of the vent gases. This requirement is based upon the safety case for the site and the operator has indicated that a basis of safety could not be established for connection of all the vents because of concerns related to ingress of air into a fuel rich vent. Thus, the capital expenditure for this site would be significant and would relate to installing the aforementioned standby incinerator.

The producers have also provided information on measures taken towards reducing emissions at sites of downstream users. These include offering special containers for secured delivery, storage and handling, including closed loop product transfer; providing suitable stabilisers and stabiliser monitoring for use in closed systems; and ensuring that distributors are audited under

the ESAD scheme²⁸, with subsequent information provision on techniques for emissions reduction.

A1.3 Industry Views on Appropriate Risk Reduction Strategy

All of the three producers have indicated that they would accept guidance on emission limit values under the IPPC regime, for which permits must be in place during 2007. They would not support the introduction of mandatory emission limit values due to the differences in plant construction.

Similarly, they have all indicated that they believe the Solvent Emissions Directive to be sufficient to address the risks for surface cleaning (this is considered by Entec elsewhere in this report).

All of the three companies indicated that they do not believe that marketing and use restrictions for manufacture and intermediate use of trichloroethylene would be appropriate. Similarly, they do not support marketing and use restrictions to use trichloroethylene only in closed equipment as they believe that this would duplicate existing legislation).

None of the producers would support any additional controls introduced through voluntary means as they do not believe that this would be workable.

A2. Formulation for Use as a Solvent

A2.1 Summary of Consultation

Two companies have been identified that undertake formulation of large quantities of trichloroethylene for use as a solvent.

In terms of the risk assessment, it was assumed that such a site could handle 30,000 tonnes of trichloroethylene per year or around 40% of non-feedstock use. This quantity would now represent a significant proportion of the non-feedstock use due to the reduction in sales in the European Union.

The two companies concerned do not 'formulate' more than around 5,000 tonnes per year in total (this relates to mixing the trichloroethylene with small amounts of stabilisers). However, the total quantity 'handled' by these companies is over two thirds of the total of around 32,500 tonnes sold for non-feedstock uses in 2004. The difference between the quantity handled and the quantity formulated simply relates to unloading and repackaging of the trichloroethylene.

These activities are not regulated under any relevant environmental legislation for control of emissions to air, though they are controlled in terms of workplace concentrations of trichloroethylene. Therefore, whilst large quantities of trichloroethylene are handled at sites other than production sites, only a relatively small proportion actually undergoes 'formulation'.

²⁸ This scheme is an industry led initiative to assess chemical suppliers and distributors to give a measurement of the commitment of distributors to their Responsible Care Programme and a common tool for suppliers to evaluate, against their individual requirements, the safety, health and environmental performance of their distributors.

A2.2 Current Controls and Potential for Further Emission Reductions

Table A2.1 provides a summary of the emissions controls in place at each of the two sites for which information has been provided for this work.

Table A2.1 Estimated Emissions at EU 'Formulation' Sites

Site	Process Description and Emissions Controls	Emissions
F1	Trichloroethylene pumped from road tanker to the stock tank and then to drums on the filling line or for formulation. Localised fume extraction at drum filling point ^[1] which is vented to atmosphere. No treatment of emissions or vapour balancing system.	Not measured or calculated. Rough estimate is of the order of kg rather than tonnes per year.
F2	All transfers of trichloroethylene within the site mentioned take place within a closed circuit.	Concentrations of trichloroethylene are reported to be not-detectable at the site boundary and emissions to air are estimated to be around 250kg per <u>year</u> (as compared to 400kg per <u>day</u> assumed for this process in the risk assessment).

[1] The extraction is very localised and potential for emissions at this stage is relatively limited: there is a 2" filling hole in the top of the drums for the filling head and there is only around 1/4" clearance. The extraction is localised at the point of filling.

In terms of potential techniques for achieving further emissions reductions, suitable techniques are likely to include thermal oxidation or absorption/adsorption for continuous vents and techniques such as vapour recovery units, tanker modifications and storage tank changes in relation to emissions from tanks and transfers. Table A2.2 includes examples of the potential costs of introducing techniques relevant to continuous vents and Table A2.3 includes relevant information in relation to storage tanks and transfers.

Table A2.2 Typical Costs of Potential Abatement Measures

Technique	Capital Cost (£ per 1000 Nm ³ /h)	Operating Cost (£ per 1000 Nm ³ /h)	Removal Efficiency
Adsorption	3,200 - 6,400 or 154,000 ^[1] for a 1000 Nm ³ /h facility	380 - 830 consumables (excludes disposal costs)	80-95%
Straight thermal oxidation	1,800 - 3,800	15,400 - 28,900	98-99.9%
Straight catalytic oxidation ^[2]	6,400 - 51,000	1,800 - 13,500	95-99%
Regenerative catalytic oxidation	15,400 - 57,000	2,300 - 7,700	90-99%

[1] Lower figures exclude regeneration of captured emissions.

[2] Catalytic oxidation may be more suitable for low concentration gas flows than thermal oxidation.

Source: Entec (2003).

Table A2.3 Example Costs of Containment During Transfer and Storage

Abatement Technique	Capital Cost (€k)	Annualised Capital Cost (€)
External floating roof - secondary seal	€39.2	€8,700
Internal floating roof	€110.6	€24,500
Road tanker modifications	€112	€24,800
Single stage VRU	€994	€220,200
Plus second stage VRU (incremental)	€161	€35,700

Values converted from £ Sterling using an assumed exchange rate of £1 = €1.4. Annualised capital costs calculated assuming a discount rate of 3.5% and assuming an investment lifetime of five years.

Source: Environment Agency (2002). Costs based on storage in two tanks of 5,000 m³ each and four road tankers included in the scope.

These techniques are all relatively high-cost options for controlling emissions and giving consideration to these options is only considered to be suitable if the emissions are indeed as high as those quoted in the risk assessment²⁹. For example, the annualised costs of catalytic oxidation might be expected to be somewhere between around €45,000-€345,000 for a single site; the annualised cost for carbon adsorption could be around €15,000-€30,000³⁰. The annualised costs of introducing modifications to road tankers and secondary seals on storage tanks could be around €33,500.

However, there would also be savings associated with avoided losses of trichloroethylene. Assuming the worst-case losses used in the risk assessment (0.4% to air), the savings per 10,000 tonnes of trichloroethylene throughput could be up to around €44,000 per year assuming that all losses could be captured. In practice, without closed systems for all aspects of a site, some losses to air would remain; additionally, the value of trichloroethylene losses abated using oxidation techniques would not be realised.

Not all of these techniques will be suitable in practice for all volume flow rates and all concentrations of trichloroethylene. For example, one of the companies has indicated that the volumes concerned and the site size would not justify thermal oxidation methods, with the only suitable option identified as activated carbon adsorption. The company indicates that the cost of this method would be high for the disposal of contaminated carbon waste. A vapour return system was considered by the company but was considered to be prohibitively expensive.

A2.3 Industry Views on Appropriate Risk Reduction Strategy

One of the companies referred to above suggests that existing controls (Solvent Emissions Directive, IPPC controls, and health protection measures) are sufficient and does not envisage the need for further legislation at present. The other company does not believe that emissions

²⁹ For example, the costs of catalytic oxidation

³⁰ Assuming straight catalytic oxidation and carbon adsorption, with a discount rate of 3.5% and assuming an investment lifetime of five years and a volume flow rate of 10,000 Nm³/h. Costs do not include regeneration of trichloroethylene or disposal of contaminated wastes.

are significant and would be unlikely to introduce emissions controls in the absence of legislation.

A3. Metal Degreasing

A3.1 Summary of Consultation

For the purposes of this risk reduction strategy, a number of companies have been contacted in relation to obtaining information on the expected route to compliance in particular. Information from five companies undertaking a large quantity of metal degreasing is included in this section. All of these companies use trichloroethylene or did in the recent past.

Note that no consultation has been undertaken with companies only using relatively small amounts of trichloroethylene in metal degreasing. It is considered unlikely that such sites would lead to an unacceptable risk to the environment (since the worst-case site considered in the risk assessment was assumed to use 20 tonnes per year and only led to a PEC/PNEC ratio of 1.5).

In addition, the Surface Engineering Association and the Engineering Employers Federation have contacted their counterpart organisations in other EU countries (see Section A3.2, below).

Of the five companies contacted, all are medium to large sized companies with turnover ranging from around €17 million to €140 million and with between 100 and over 1000 employees. Table A3.1 provides a summary of the key products for which trichloroethylene is used by these companies. The total consumption of trichloroethylene by these companies is around 430 tonnes per year.

Table A3.1 Products and Reasons for Use in Metal Degreasing (consultation responses)

Company	Uses of Trichloroethylene	Reasons for Use
S1	Metal tubes - various applications	Best product for this use
S2	Electro-ceramics used in piezoelectrics (e.g. for ultrasonics and sensors in hightech and aeronautics industries). Products are made by passing very high voltages across them in hot oil. They are subsequently degreased in hot (c. 85°C) trichloroethylene.	Most effective solvent for degreasing
S3	Production of nickel alloy tubes including fine bore (<1 cm diameter) and up to 12 meters in length. Trichloroethylene used for degreasing of oils from processing.	Most effective degreaser for the removal of oils especially for fine bore tubes which must be effectively cleaned. Customers (including aerospace industry) require use of solvents for cleaning, any process change requires customer approval.
S4 ^[1]	Degreasing copper tubing (including for technical and medical uses). Now substituted with methylene chloride.	Customers for e.g. medical uses stipulate the use of chlorinated solvents as the carbon on metal surface in strictly limited.
S5	Radiators and intercoolers - degreasing of components including fine bore tubes. Oil is used in production and degreasing required for effective oil removal.	Trichloroethylene is essential for removal of oil particularly from fine tubes.

[1] No longer uses trichloroethylene.

Based on the information from consultation in Table A3.1, a number of key points emerge. Firstly, it is evident that one of the main processes in which trichloroethylene is used is in production of metal tubes (four of the five companies listed). Secondly, two of the companies indicated that contractual obligations with the aerospace and medical industries require the use of chlorinated solvents or trichloroethylene specifically. This would tend to make any substitution more problematic than simply finding an appropriate alternative technical solution.

A3.2 Current Controls and Potential for Further Emission Reductions

Discussions were held with the aforementioned companies regarding the current control measures in place, as well as the potential for further reductions in emissions. Since these companies will all have to comply with the Solvent Emissions Directive by 2007, the discussions are framed in the context of their expected route to compliance. Table A3.2 provides information on each company in the form of case studies on this issue. Consideration is also given in this section to potential substitutes for trichloroethylene, since this is one of the principal actions specified under the Solvent Emissions Directive.

Table A3.2 Case Studies on Metal Degreasing and Potential Further Emissions Reductions

Company	Information on Emissions and Expected Route to Compliance with SED
S1	<p>The company currently has two open tanks of around 12m in length, as well as one small enclosed system. Gases are vented as part of their IPPC permit. Both types vent to atmosphere and so all three systems above will have to be scrapped in order to comply with the SED since there is no option to modify the equipment to comply. Thus, the only options are to substitute trichloroethylene and/or to invest in fully enclosed equipment. The predicted capital cost of replacing systems would be £1.5m (around €2.1 million) plus operational costs associated with the increased cycle time of around 30 minutes compared to the current 3 - 9 minutes.</p> <p>The company has tried a number of alternatives including aqueous, CO₂ (dry ice), modified alcohols and brominated solvent (unable to name exact substance). The first three were unsuccessful and there were perceived health (occupational exposure) issues associated with the use of the brominated solvent. Methylene chloride would be the preferred alternative but the stabilisers are stripped out by the activated carbon filters. The stabilisers then have to be continually monitored and added with consequences for cost. Tetrachloroethylene is the only viable alternative, however this will be more expensive. They currently pay £0.51 per litre for trichloroethylene whereas the cost of tetrachloroethylene is £1.70 per litre.</p>
S2	<p>Components are degreased in enclosed degreasers (i.e. eliminating operator exposure and venting to atmosphere). One small open system is used but c. 98% of use is in the enclosed system. Enclosed systems prevent exposure and use cooling coils to collect vapour.</p> <p>Some difficulty is envisaged in compliance with the SED. Current usage of around 8-10 tpa may be reduced through optimisation of processes and better operator use (for example some operators may remove components from automatic degreasers before drying and therefore release more vapour) and capital investment in new equipment. It is believed that consumption could be reduced by around a half but not below the 1 t/yr threshold (this could be done by identification of the processes with the largest losses). The company does not currently monitor concentrations of trichloroethylene in vent gases.</p> <p>Where appropriate, the company has introduced aqueous washing procedures, rather than using trichloroethylene. The aforementioned equipment is expected to cost in the region of £250k (€350k).</p> <p>Have tried natural citrus based products as alternatives (unsuccessfully). The most viable alternative solvent is methylene chloride and tetrachloroethylene. The former could also save energy because of its lower boiling point i.e. hot baths for tric at 70-80 oC and for methylene chloride 30oC. The same equipment can be used for methylene chloride, but the product may be more costly.</p>
S3	<p>The company has a very large open tank system (12m in length and 8m deep). The tank has an extraction unit for venting to air including a carbon recovery unit on stack and cooling coils.</p> <p>They are currently evaluating a number of options for compliance with the SED, including the use of aqueous cleaning and alternative solvents. Reduction to meet the 1 tpa consumption threshold for exclusion from the SED is not an appropriate option nor is reduction of emissions to 2mg/m³ so alternatives to trichloroethylene currently appear to be best option.</p> <p>Identified alternatives include tetrachloroethylene, methylene chloride and aqueous cleaning. These have been evaluated in laboratory scale tests, although trichloroethylene is still considered the best option for degreasing. Their tests show that residual grease is left on products with use of alternatives (as part of the finishing process, tubes pass through a furnace and residual oils and solvent cause unacceptable staining). The estimated capital cost of substituting trichloroethylene is £1m (€1.4m), with no further operational costs expected.</p>
S4 ^[1]	<p>The company has substituted trichloroethylene for methylene chloride as a result of the impending SED requirements (at the end of 2003). Their current systems are of the open type with a hood that vents to atmosphere (some vapour is captured by cooling coils). The company tried aqueous alternatives but these were found to corrode the metal surface (which must be very clean for medical use etc.) unless dried rapidly. Emissions of methylene chloride are currently controlled under the company's IPPC permit.</p> <p>Methylene chloride is considered by this company to be better for hot degreasing as since it does not need to be heated to as high a temperature. Similar costs are expected as the same equipment is used (although they have a capital plan to modify equipment to increase efficiency and further decrease solvent emissions which will cost around £100k, €140k) c £97,000 next year).</p>

Company	Information on Emissions and Expected Route to Compliance with SED
S5	<p>The company is currently regulated by the local authority (not covered by the IPPC Directive) in relation to solvent emissions and other relevant controls. The company uses a fully enclosed system but this vents to atmosphere. The company will be unable to reduce their emissions to below the 1 tpa SED threshold.</p> <p>They are currently considering other solvent alternatives and process changes. For example, they are testing the use of oils that may be heated off at around 200°C, rather than removed using a solvent such as trichloroethylene.</p> <p>The company could potentially introduce an enclosed system that does not vent to atmosphere and they believe that this would cost around £50k (€80k), with no expected change in operational expenditure.</p>

[1] No longer uses trichloroethylene.

A number of conclusions regarding companies approaches to compliance with the Solvent Emissions Directive can be drawn from Table A3.2:

- Not all companies have yet decided how they will comply with the requirements of the Directive.
- The companies contacted are generally attempting to substitute trichloroethylene due to the Solvent Emissions Directive requirements. This is due to the suggested replacement of the substance under the Directive and also because companies are unlikely to be able to meet the low emission limit for the substance in some cases.
- The main substitutes identified for these applications include methylene chloride and tetrachloroethylene. Aqueous cleaning is also appropriate in some cases and removal of the requirement for cleaning may also be appropriate (using oils that are heated off).

Although direct contact with companies was limited to UK-based companies, these conclusions are expected to be true for all EU Member States. Through the Council of European Employers of the Metal, Engineering and Technology-based Industries (CEEMET), the representative Italian trade association has indicated that companies will generally substitute trichloroethylene, replacing it with water-based solvents, perchloroethylene or low-boiling hydrocarbons. Other techniques to comply include closed loop systems with solvent recovery. All companies are expected to comply with the requirements of the Directive by 2007.

In addition, a number of members of the European Committee for Surface Treatment - the European equivalent to the Surface Engineering Association in the UK - have indicated that the route to compliance is expected to be similar to that in the UK, also noting that some countries may go further than what is already required under the Solvent Emissions Directive.

In addition, consultation has been undertaken with a supplier of machines for surface cleaning to determine the extent to which equipment is available to comply with the emission limits in the Solvent Emissions Directive. Based on these discussions, it has been confirmed that emissions from the closed type machines currently available are minimal and certainly within the emission limits specified under the SED. Where closed machines can be used, the machines are compliant with the SED due to the low consumption involved (almost always less than 1 tonne per year).

This company provided details of a large organisation using trichloroethylene in metal degreasing. The company reduced consumption through use of a closed machine by 99.2% to around 150kg per year. This equates to a reduction in consumption of 18.6 tonnes per year, with an associated saving in raw material costs of around €20,500³¹. Thus, whilst there will be costs for many companies in enclosing the surface cleaning process, significant cost savings may be made in many cases.

However, it should be noted that not all processes will necessarily be able to use alternative machines and in such cases substitution of trichloroethylene is likely to be the most appropriate route to compliance with the SED (for substances with less stringent emission limits). Substituting trichloroethylene for tetrachloroethylene could potentially be very expensive: one of the companies consulted suggested a price increase of more than 200%, although in some cases the price may be only marginally higher.

A3.3 Potential Substitutes for Trichloroethylene

As detailed above, the main potential substitutes for trichloroethylene appear to be tetrachloroethylene and methylene chloride. Aqueous cleaning may be suitable for some - but by no means all - applications. Other alternatives that have been suggested include bromopropane and bromochloromethane, as well as use of oils that require heating rather than solvents for removal.

A4. Use as an Intermediate

A4.1 Summary of Consultation

For the purposes of this risk reduction strategy, consultation has been undertaken with four companies using trichloroethylene as a feedstock in production of other chemicals (three EU sites plus one outside the EU). These sites represent the majority of feedstock use of trichloroethylene in the EU.

A questionnaire was circulated to all four companies and questionnaires were returned by all companies. At one of the sites concerned, production of trichloroethylene also takes place.

All of the companies in question are considered to be large companies, although the part of the business associated with use of trichloroethylene is smaller in some cases (e.g. only 50-250 employees).

Trichloroethylene is used by all of these companies in production of the refrigerant HFC-134a (1,1,1,2-tetrafluoroethane) which is used in mobile and stationary air conditioning; refrigerators/freezers; and as a blowing agent for polystyrene foams.

One of the companies has indicated that production of HFC-134a using trichloroethylene ceased for the foreseeable future in October 2004.

³¹ Based on a price per tonne of €1100.

A4.2 Current Controls and Potential for Further Emission Reductions

Table A4.1 provides a summary of data on emissions and current controls from the companies contacted for the purposes of this study.

Table A4.1 Estimated Emissions at Sites using Trichloroethylene as an Intermediate

Site	Emissions Controls	Emissions
I1	Closed system, but no emission controls. Trichloroethylene is used and consumed as intermediate product.	Bellow 1 ppm in wastewater. Not detectable in vent gases of incineration unit. Total below 1 tonne per year of volatile emissions.
I2	Trichloroethylene is used in closed apparatus.	No emission reported during unloading (vapour balancing) or from pressurized storage. Trichloroethylene completely converted into other products with no trichloroethylene emission in the process vent to the atmosphere. Workplace monitoring in the unloading area indicates average values less than 2 mg/m ³ . No monitoring of emissions at site boundary as not considered necessary by company.
I3	Drum couplings on tanker connections. Stock tanks vented into the process rather than to atmosphere.	Less than 10 mg/m ³ in vent gases and site boundary. Less than 20 kg for 2004. Note these totals are overestimates and relate mainly to reporting half of the limit of detection where trichloroethylene is not detected.
I4	Used in closed system with secondary containment around the storage tank. Trichloroethylene is consumed in the reaction of the process. Site has a Leak Detection and Repair (LDAR) system.	Most vent gases are treated in a Thermal Oxidation unit and emissions are approximately 0.02%.

Site I4 is not in the European Union.

It is possible to compare the emissions reported in Table A4.1 with the conclusions of the environmental risk assessment: this assumed an emission factor to air of 0.1%, given that the information available was not considered to be sufficiently representative. Whilst the most recent information indicates that emissions from all sites are less than the 0.1% assumed in the risk assessment, data are not collected for all sites.

While the information available on use of trichloroethylene as a feedstock in production of other chemicals suggests that the sites identified are unlikely to pose an unacceptable risk for the environment, there is insufficient data collected for all sites to adequately demonstrate this.

However, there already exists a regulatory regime (Integrated Pollution Prevention and Control) under which all of the sites using large quantities of trichloroethylene will be regulated. This is likely to provide an appropriate means to ensure that emissions to air are suitably controlled, taking into account the best available techniques for emissions control.

A4.3 Potential Substitutes for Trichloroethylene

None of the companies contacted identified any potential substitutes that would be suitable for use in their current plant. There are alternative routes to synthesis of HFC-134a, though their production would require different plant/equipment.

Appendix B

Summary Analysis of Possible Substitutes

Table B1 presents a summary of available physico-chemical and hazard data for four possible alternatives to trichloroethylene in hot vapour degreasing. Where possible, these data were taken from IUCLID data sets via the European Chemicals Bureau's ESIS (European Substances Information System) database and the Swedish Chemicals Inspectorate (Kemi) 'N-Class' data base for classification for the environment. Bromochloromethane and 1-bromopropane did not have IUCLID data sets and bromochloromethane was not listed on the N-class database. Where summary data were missing data provided by the International Programme on Chemical Safety (IPCS) International Chemical Safety Cards (ICSCs) were used. Henry's law constants were calculated using vapour pressure, molecular weight and water solubility data.

Of the four substances considered, tetrachloroethylene is the only substance on an existing substances regulations (ESR) priority list, it is currently subject to risk assessment under ESR. Bromochloromethane, is subject to control under EC regulation 2037/2000 on substances that deplete the ozone layer (with minor exemptions for laboratory and analytical uses).

Considering classification for the environment, it can be seen from Table B1 that trichloroethylene has the risk phrase R52/53³² ('Harmful to the environment' and 'May cause long-term adverse effects in the aquatic environment'). Tetrachloroethylene is however more hazardous to the aquatic environment as is it classified as N;R51/53 ('Toxic to aquatic organisms' and 'May cause long-term adverse effects in the aquatic environment'). Neither 1-bromopropane nor dichloromethane are classified as dangerous for the environment. Although bromochloromethane is not currently listed as classified under Annex 1 of directive 67/548/EEC, it is listed as an ozone depleting substances and banned from use as a degreaser under EC regulation 2037/2000 (as amended by regulation R1804/2003). Consequently, this substance could therefore be classified as N;R59 ('Dangerous to the ozone layer'). Moreover, as it is banned for use it cannot therefore be considered as an alternative for trichloroethylene.

The two substances that are not classified as dangerous for the environment in Table B1, namely 1-bromopropane and dichloromethane are both classified for hazards to human health. The substance 1-bromopropane is classified as harmful (Xn) owing to the danger of serious damage to health by prolonged exposure through inhalation (R48/20) and as an irritant (Xi) to eyes, respiratory system and skin (R36/37/38). Furthermore, 1-bromopropane is a reproductive toxin (i.e. a chemical that produces or increases the incidence of non-heritable effects in progeny and/or an impairment in reproductive functions or capacity) category 2, on the basis that it may impair fertility (R60) and category 3 as it presents a possible risk of harm to the unborn child (R63). Like tetrachloroethylene, dichloromethane is a category 3 carcinogen on the basis of limited evidence of a carcinogenic effect.

³² NB this is not preceded by 'N', only risk phrases that include hazards that are very toxic or toxic to aquatic organisms are preceded by 'N' - see Annex VI of Directive 92/32/EEC.

Table B1 Comparison of trichloroethylene with some possible substitutes (physico-chemical and environmental hazard data)

Substance	Trichloroethylene	Tetrachloroethylene	1-bromopropane	Dichloromethane	Bromochloromethane
Synonyms		Perchloroethylene	n-propyl bromide	Methylene chloride	BCM, Halon 1011
CAS number	79-01-6	127-18-4	106-94-5	75-09-2	74-97-5
EINECS	201-167-4	204-825-9	203-445-0	200-838-9	200-826-3
Melting point	-84.8	-22 °C	-110 °C	-86.5	-86.5 °C
Boiling point	86.8 °C	121 °C	71 °C	39-40 °C at 1013 hPa	68.1 °C
Relative density	1.465 g cm ⁻³	1.62-1.626 g cm ⁻³ at 20 °C	1.35 g cm ⁻³	1.934 at 20 °C	1.934 at 20 °C
Vapour pressure	8.6 kPa at 20 °C	1.9 kPa at 20 °C	13.3 kPa at 18 °C	47.4 kPa at 20 °C	15.6 kPa at 20 °C
Water solubility	1.1 g l ⁻¹	1.6 g l ⁻¹ at 20 °C	2.5 g l ⁻¹	13.7g l ⁻¹	4.0 g l ⁻¹
Octanol-water partition coefficient	2.29	2.53-2.88 at 20 °C	2.1	1.25 at 25 °C	4.0
Henry's Law constant	1.025·10 ⁻³ Pa m ³ mole ⁻¹	2.1·10 ⁻³ Pa m ³ mole ⁻¹	3.07·10 ⁻⁴ Pa m ³ mole ⁻¹	6.54·10 ⁻⁴ Pa m ³ mole ⁻¹	5.05·10 ⁻⁴ Pa m ³ mole ⁻¹
Flash point	No data	No data	21 °C	No data	No data
Auto-ignition	410 °C (auto-flammability)	No data	490 °C	605-662 °C (auto-flammability)	No data
Explosivity	Not explosive	Not explosive	No data	Not explosive	No data
Current classification for the environment	R52-53	N:R51/53	Not classified	Not classified	Not listed under Annex 1 of 67/548/EEC
Possible classification for the					N;59

XVII

Substance	Trichloroethylene	Tetrachloroethylene	1-bromopropane	Dichloromethane	Bromochloromethane
environment					
Health classification	Carc. Cat 2;R45 Muta. Cat.3; R68 Xi;R36/38, R67	Carc. Cat 3; R40.	F;R11 Rep Cat 2; R60- Rep Cat 3; R63 Xn;R48/20 - Xi R36/37/38 - R67	Carc. Cat 3;R40	
Other information					Ozone depleting substance banned for use as a degreaser under EC regulation 2037/2000 (as amended by regulation R1804/2003) See also HSE CHAN15 (revised)

Appendix C

Organisations Consulted

Arkema

BA Tubes

Chemical Recyclers Association

Council of European Employers of the Metal, Engineering and Technology-based Industries (CEEMET)

Defra AEQ Division

Denso Marston

Dow Chemical

European Chlorinated Solvents Association

Engineering Employers Federation

European Fluorocarbons Technical Committee

Environment Agency for England and Wales

Association of European Adhesives Manufacturers (FEICA)

Health and Safety Executive

Honeywell International

Ineos Chlor

Ineos Fluor

Midland Oil Refiners

Morgan Electroceramics

Mueller Europe Ltd

P&R Services

Surface Engineering Association

Solvay

Special Metals Wiggins Ltd

Virotec Ltd

Note: Two companies requested that their details be excluded from this list.

Appendix D

Recycling of Trichloroethylene

Recent legislative developments have led to an increased need to reduce emissions and losses of trichloroethylene and other solvents, as well as to recover various wastes. This has led to an increase in the recycling of solvents such as trichloroethylene. This section provides some background information on the recycling of trichloroethylene.

The recycling of solvents works by segregation of the solvent fraction of a waste stream through the use of distillation technology. This is accomplished by heating the fluid to specific temperatures in distillation columns, causing the volatilisation of the specific solvent portion based on individual boiling points, which for trichloroethylene is 86-88°C. This can be achieved through various technologies, the most common being vacuum stills, thin layer evaporators and sieve tray fractionation columns.

The solvent is then recovered through the use of refrigerated heat exchangers, where condensation occurs and the solvent in its pure form is collected in a collection pot or chamber. It is then tested for quality control and purity and then either sold onto a third party or returned to the original consignor. Figure D1 explains this process diagrammatically.

Whilst the recycling of spent solvent (or wastes containing spent solvent) is not in itself a listed activity under the Solvent Emissions Directive, it is covered under the waste management provisions of the Integrated Pollution Prevention and Control regime (see Section 3).

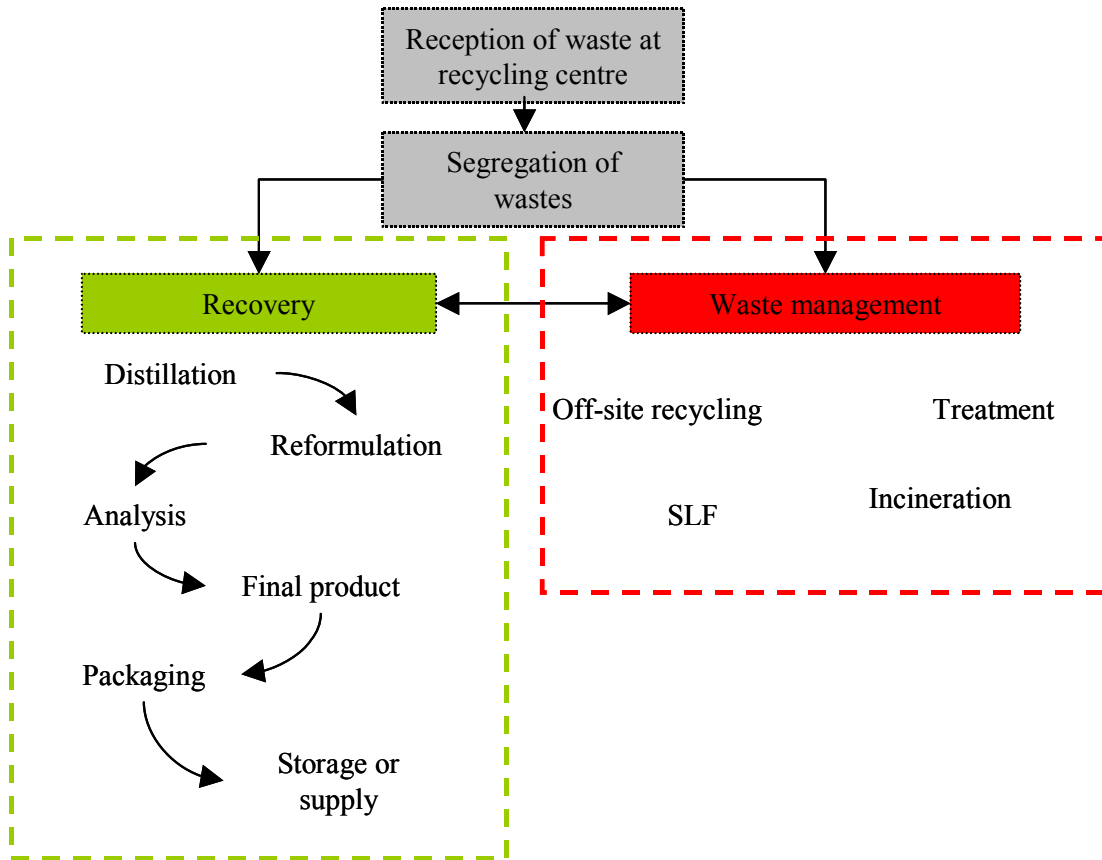
In the UK, environmental benchmark emissions (“environmental assessment levels”) have been set for trichloroethylene as 1.1 mg/m³ (8 hour) and 1.0 mg/m³ (15 minute). These are considered to be provisional environmental benchmarks and are used as an indicator of a degree of environmental impact that can be considered acceptable for a particular substance to a receptor or environmental medium (Environment Agency, 2003).

There is little direct information available on the actual extent of solvent recycling within the EU and despite extensive literature searches, there are no conclusive figures on the amount of trichloroethylene currently being recycled compared to that being used. Given that no need for limiting the risks from this process have been identified, this has not been investigated further.

In general, it is clear that there has been a consistent drop in the emissions of trichloroethylene from waste disposal companies (for example, based on the Environment Agency’s Pollution Inventory and the EPER database), this is likely to be due both to the reduction in use (and hence disposal) of trichloroethylene and because a greater percentage is expected to be sent for recycling than had been previously.

Based on a review of relevant literature and information provided by industry, it is evident that there are numerous service providers who offer a chlorinated solvent recycling service or on-site provision for direct recycling. Review of available literature does however suggest that recycling of chlorinated solvents is more difficult than non-chlorinated solvents, the preferable method being azeotropic vacuum distillation. Additionally, the markets for reclaimed chlorinated solvents may not be as strong as for non-chlorinated solvents.

Figure D1 Solvent Recycling Process (adapted from Distillex, 2004)



In the United Kingdom, there are thought to be three main companies undertaking recycling of trichloroethylene. Whilst the recycling of trichloroethylene has increased in recent years, along with other chlorinated solvents, the total quantities recycled are not expected to increase significantly in the future due to a general move away from use of chlorinated solvents. Anecdotal information suggests that around 300,000 tonnes of solvents are recycled in the UK each year, of which around 20,000 tonnes is expected to be chlorinated solvents (this does not include solvents recycled on-site but to dedicated solvent recovery plant). Overall, supply of trichloroethylene from recyclers in the UK could be around 1,000 tonnes per year (although no comprehensive data have been collated for this risk reduction strategy).

In some cases, trichloroethylene may be 'recovered' for use as a secondary liquid fuel when the purity renders it inappropriate for further use; due to its relatively low calorific value, it is generally burned in cement kilns, along with other fuels.

Two of the larger companies recycling trichloroethylene in the UK have been contacted for the purposes of developing the risk reduction strategy. Their combined emissions are not thought to exceed 2.5 tonnes per year. This level of emissions would be unlikely to pose a risk to the environment based on the conclusions of the environmental risk assessment.