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ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA

INVESTIGATION INTO LOSSES TO THE
ENVIRONMENT DURING PROCESSING
OR USAGE OF SELECTED
HYDROCARBON SOLVENTS
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March, 1983

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ABSTRACT

A study was conducted to inventory and characterize the use of methylene chloride, trichloroethylene, perchloroethylene and 1,1,1-trichloroethane by selected processors and end users in British Columbia industry. Ten sites were assessed to determine and characterize specific processes or uses that result in human or environmental exposure to the selected solvents.

In 1981, British Columbia industry used 2316 tonnes of the selected chlorinated solvents. This quantity was approximately 0.1% of the total North American consumption during the same year. In general it appears that the environmental impact of the chlorinated solvents in British Columbia is minimal.

The major impact is in localized workplaces when poor operating practices occur. Evaporation during use is the major source of entry to the environment, accounting for as much as 90% of solvent losses. The literature indicates that solvents in the atmosphere would be rapidly degraded. Solid wastes from processes may constitute from 10-15% of the solvent losses. Liquid wastes are generally minimal.

Much of the industry has recently incorporated, or is in the process of incorporating, design changes which minimize the release of solvents. The activity can be attributed to: increasing costs of the selected solvents; concern for worker health; and efforts of manufacturers and distributors of solvents and equipment to improve controls on solvent use. Manufacturers and distributors have undertaken an aggressive self-regulatory approach by provision of educational material and technical support for equipment design, use practices, and disposal procedures.

The most effective regulatory control of chlorinated solvents in British Columbia is that of the Workers' Compensation Board (WCB). The WCB regulations are intended for worker safety. However, the regulations generally simultaneously minimize releases to the environment.

Areas of concern identified in this study include: the lack of approved waste disposal facilities in British Columbia; imposition of taxes on equipment meant to reduce emissions; and poor industry-regulatory agency liaison.

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CONCLUSIONS

1. Use of chlorinated solvents in British Columbia (2316 tonnes in 1981) is very low compared to the quantity used in all of North America (estimated 2,000,000 tonnes in 1981).
2. Chlorinated solvents are mainly used in British Columbia for dry cleaning, degreasing, paint removal, and product formulation.
3. It does not appear that chlorinated solvents constitute a hazard to the B.C. environment. The concern, if any, would more likely be restricted to particular workplaces.
4. Evaporation constitutes the major route of solvent losses.
5. Primary wastes are sludges which may contain up to 20% solvent. Wastewaters would contain minimal quantities of solvents.
6. Poor operating practices contribute significantly to solvent consumption, however, manufacturers and suppliers of solvents are aggressively pursuing the elimination of such practices.
7. Design changes to process equipment can significantly reduce solvent losses. Incentives to incorporate such changes include rising costs of solvents, and concern for human health. Deterrents to incorporation of such changes include high costs of capital acquisition and the federal, provincial and municipal tax structure.
8. Suppliers and producers of solvents offer upon request extensive technical support for equipment design, use practices and emergency response. Utilization of this support varies among users. Government agencies are generally unaware of the extent of the technical support offered.

9. Disposal of sludges or spent solvent is a major dilemma facing solvent users in B.C., because approved disposal facilities do not exist in B.C.
10. The most effective regulatory controls of solvent usage in B.C. are those of the Workers' Compensation Board. Although the controls are meant to assure worker safety, the controls simultaneously minimize releases to the environment.
11. There does not appear to be any need for further legislation in B.C. regarding the use of chlorinated solvents. If legislation is required, it must be part of national or international legislation to reduce global emissions of chlorinated solvents.
12. There is minimal external and internal uniformity among regulatory agencies in assessment of industry practices.

RECOMMENDATIONS

1. In light of the large existing data base on appropriate use practices with chlorinated solvents, it is recommended that all users be encouraged to utilize the existing resources and knowledge. One mechanism to ensure such utility would be that regulatory agencies make themselves more of a resource for solving problems rather than undertaking the current inherent role of defining or assuming problems.
2. To function as a resource, it is recommended that regulatory agencies have process specialists to enable uniform province-wide assessments of use practices and recommendations. The specialists should ensure continued liaison with manufacturers, suppliers, trade associations, and users.
3. It is recommended that waste disposal alternatives be defined to users of chlorinated solvents (in addition to shipment of wastes to the United States). The lack of alternatives is resulting in variable disposal practices. In some cases the ultimate fate of the wastes is unknown.
4. It is recommended that taxation incentives be considered at all levels of government to encourage the installation of process equipment or pollution control equipment which would minimize release of contaminants to the environment.

I INTRODUCTION

The Department of the Environment and the Department of National Health and Welfare have published a "list of Priority Chemicals (which) includes those substances for which regulations are being developed under the Environmental Contaminants Act or concerning which further study and information are required to determine whether regulation or other action is necessary" (Canada Gazette Part I, January 16, 1982). The chemicals were selected on the basis of three criteria:

1. Toxic effects: when evaluation of scientific data indicated that a chemical substance could cause or causes adverse effects on human health or the environment.
2. Persistence: where evaluation of scientific data indicated that the chemical substance accumulates or could accumulate to significant concentrations in air, water, soil, sediment or tissue.
3. Quantity and use: where data indicate that the substance is imported, manufactured or processed in Canada and could enter or has entered the environment in significant quantities.

The List of Priority Chemicals designates chloroethanes, chloroethylenes, and chloromethanes as "substances which may pose a significant danger to human health or the environment and about which further detailed study or information (for example, toxicology, amounts used or concentrations in the environment) is necessary". To provide additional information on possible hazards posed by these substances, the Environmental Protection Service-Pacific Region commissioned a study to investigate losses to the environment during processing or usage of those substances in British Columbia. Four specific solvents (methylene chloride, trichlorethylene, perchloroethylene, and 1,1,1-trichloroethane) in widespread and diverse use in B.C. were selected as a focus for the study.

1.1 Review of Concerns Related to Chlorinated Solvents

Chloroethanes, chloroethylenes and chloromethanes have been detected in sewage and industrial effluents, surface waters, ground waters, air, and soils. The widespread distribution of these compounds has raised concerns about their effects on the environment. These concerns are based primarily on human health rather than effects on aquatic biota or wildlife. Laboratory studies have not been able to consistently prove that chlorinated solvents such as trichloroethylene and perchloroethylene are carcinogenic and the attitude of environmental and health agencies towards the presence of the compounds in the general environment is primarily one of caution. The caution is also a result of existing occupational health data which show that excessive exposure (such as in a confined, unventilated workplace) to various chlorinated solvents could result in various acute effects including death. No effects of chlorinated solvents on human health outside of places of production or use have been documented in the literature. A brief review of existing occupational health data is provided in Appendices I and II of this report.

The effects of chloroethanes, chloroethylenes and chloromethanes on aquatic biota are of lesser concern than effects on human health because the substances are usually not found in waters at levels which would cause toxic effects to aquatic biota. Exceptions include situations resulting from large spills due to accidents during transportation or storage. A review of known toxicity to aquatic biota of the substances is found in Appendix I.

Another more recent environmental concern is with respect to the reduction, by atmospheric halogenated hydrocarbons, of the stratospheric ozone layer which shields the earth's surface from biologically-affecting ultraviolet radiation. The hydrocarbons implicated include 1, 1, 1-trichloroethane (Khalil and Rasmussen, 1981) and trichloroethylene (Lapp, 1980). As a result, the U.S. EPA is considering remedial measures which will reduce atmospheric emissions of ozone-depleting halogenated hydrocarbons.

1.2 Review of Uses and Sources of Environmental Release

A review of the physical properties of the chlorinated ethanes, ethylenes and methanes, readily suggests their probable uses. The physical properties are:

- o nonflammability under most conditions;
- o ability to readily dissolve other organic compounds such as fats, oils and waxes;
- o high vapor pressures which enable ready evaporation upon exposure to the atmosphere; and,
- o densities greater than water.

Appendices I and II describe the physical properties in greater detail. Industrial applications which exploit these properties include dry-cleaning, degreasing, adhesive preparations, and chemical formulations. Table I.1 illustrates the variety of uses for four chlorinated solvents which are of major interest to this study.

Sources of environmental release therefore include:

- o manufacture of solvents;
- o emissions during use of solvents or use of products containing solvents;
- o disposal of products containing solvents;
- o and, disposal of wastes resulting from use of solvents such as degreasing wastes and dry-cleaning "muck".

TABLE 1.1 Industrial uses of selected chlorinated solvents

Compound	Formula	Uses
Methylene chloride (methylene dichloride, dichloromethane)	CH ₂ Cl ₂	Paint and varnish removers, fungicides, solvents, cleaners, pressurized spray products, fire extinguishers, Christmas tree bubble lights, carbon removers and brush cleaners, manufacture of photographic film, degreasing, diphasic treatment of metal surfaces, stripper of photoresist or screen inks during circuit board fabrication, carrier in rapid-dry paints, extracting heat-sensitive edible fats and essential oils (decaffeination of coffee), plastics processing, blowing agent in urethane foams.
1,1,1-Trichloroethane (methyl chloroform)	CH ₃ CCl ₃	Degreasing, type cleaners, color film insecticides, spot removers, cement and adhesives, fabric cleaning solutions, developer of dry film resists and stripper of screen inks for circuit board fabrication.
Trichloroethylene	CHCl:CCl ₂	Vapor degreasing, food and drug extraction, dry-cleaning, solvent for textile industry (carrier solvent for textile spotting fluids and used for dissolving polycarbonate basting threads during garment manufacture), fur cleaning, motion picture film cleaning, diluent or carrier in paints, solvent base for adhesives and varnishes, paint remover formulations, solvent base for metal phosphating systems, refrigerant and heat exchange liquid, intermediate in synthesis of glycolic and dichloroacetic acid, chain-transfer agent in PVC production, analgesic and general anesthetic, aerospace operations (flushing liquid oxygen).
Perchloroethylene (tetrachloroethylene)	Cl ₂ C:CCl ₂	Dry-cleaning solvent, vapor degreasing solvent, drying agent for metals and certain other solids, vermifuge, heat-transfer medium, manufacture of fluorocarbons.

1.3 Terms of Reference and Purpose of Study

In view of the many uses of chlorinated ethanes, ethylenes and methanes, their high volume of use, potential toxicity and likelihood of escape to the environment, EPS - Pacific Region has commissioned this study to:

- o inventory and characterize the use of chlorinated ethylene, ethane, and methylene chloride solvents by selected product formulators and end users in British Columbia industry,
- o determine and characterize specific processes or uses that result in human or environmental exposure including losses occurring from use, storage, transportation and disposal of designated chemicals.

The information for the study was to be compiled on the basis of existing EPS documentation and contacts with selected product formulators and end users. The following information was to be compiled:

- o identification of designated chemical(s) used - chemical name and quantities (kg/yr),
- o description of processes utilizing the designated chemical(s),
- o description of those components of processes which result in losses to the environment including losses from storage, transportation, and ultimate disposal of unused or waste solvents,
- o review and compilation of all available waste characterization data applicable to the use or processing of the designated chemicals,
- o review of environmental monitoring data,
- o determination of potential occupational health risks due to exposure of workers to the selected chemicals.

2 STUDY APPROACH

2.1 Review of Existing Information

A computer search of the literature was carried out to retrieve information about chlorinated solvents. NTIS (U.S. Government publications), Pollution Abstracts and CENV (Environment Canada) were among the data bases searched. Most reports were retrieved by microfiche, and Appendix III provides bibliographic citations of these reports.

Subsequently, a review was initiated of a previous EPS report "Nationwide Quantity/Location Inventories for Chlorinated and Aromatic Hydrocarbons" prepared by Acres Consulting Ltd. The Acres report provided preliminary information on quantities of methylene chloride, trichloroethane, trichloroethylene and perchloroethylene used in British Columbia. The data provided in the Acres report were not considered adequate for identification of processors and end users in British Columbia. Therefore, discussions were required with manufacturers and distributors.

2.2 Personal Contacts

Telephone and/or personal contact was made with manufacturers and distributors of the designated chemicals. The companies included C-I-L Inc., Dow Chemical Canada Inc., Canadian Hanson (a subsidiary of C-I-L Inc.), Van Waters and Rogers Ltd., Harrisons and Crosfield (Canada) Ltd., Tessier Brothers Ltd., and Baron-Blakeslee (Portland, Oregon). A written response to questions about solvent usage was received from the Dow Chemical Canada Inc. "Chlorinated Solvents Issue Management Team". The manufacturers and distributors provided helpful information on general quantities of use in British Columbia, an assessment of types of users and processors, and assessment of general use practices. Telephone discussions and visits also occurred with representatives of environmental and occupational health agencies including: Workers' Compensation Board of B.C.; the Waste Management Branch of the B.C. Ministry of Environment; the Greater Vancouver Regional District; and, the U.S. Environmental Protection Agency.

Representative product formulators and end users were then visited to observe usage of the designated chemicals and to determine the usage quantities, disposal practices, and concerns, if any, associated with use of the chemicals. Cooperation of industry was voluntary, and we are appreciative of those industries which did cooperate with this project.

2.3 Scope and Extent of Industry Coverage

Information on solvent use practices was obtained through discussions and on-site visits to selected manufacturers, distributors and users of the subject solvents. Candidates for interviews were selected so as to ensure representation of:

- o all major solvent use categories,
- o all large volume solvent users,
- o industry personnel with expert knowledge of a particular industry,
- o industry personnel with broad knowledge of the overall solvent user industry.

It is estimated that manufacturers and distributors interviewed supply more than 90% of the total solvent purchased in B.C. Discussions with product formulators included companies whose production represented 40% of solvent use for domestic products and 44% of solvent use for industrial products manufactured in B.C. Discussions with end users included companies whose solvent consumption represented 37% of all solvent purchased for direct industrial use in B.C. Discussion with knowledgeable industry spokesmen, and telephone discussions with several firms which were not visited ensured that the information obtained in this study presents a reasonably accurate picture of solvent use practices in B.C.

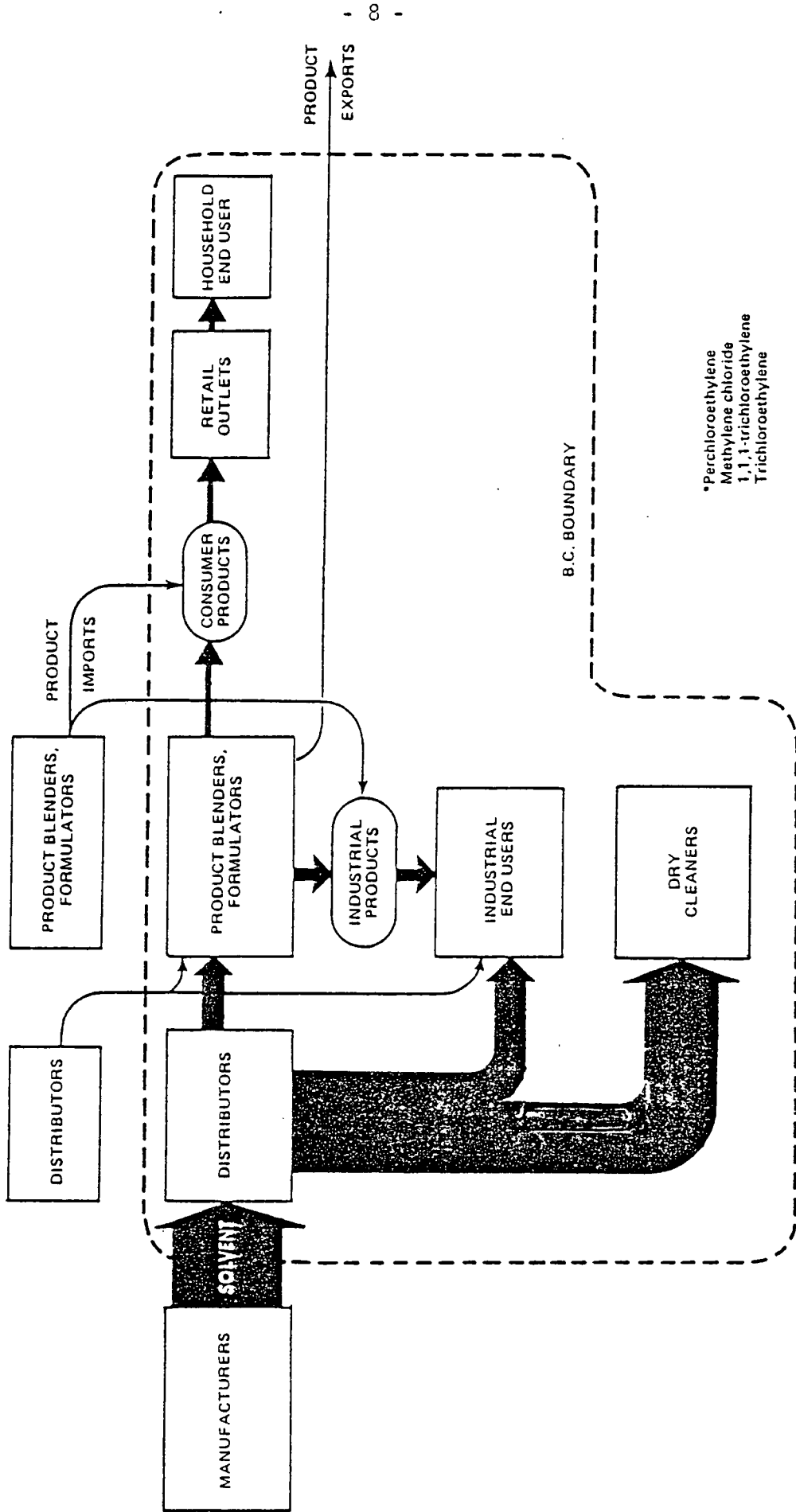


FIGURE 3.1.1 : AN OVERVIEW OF THE DISTRIBUTION OF CHLORINATED HYDROCARBON SOLVENTS* IN BRITISH COLUMBIA

3 RESULTS AND DISCUSSION

3.1 Chlorinated Solvent Distribution and Use

3.1.1 Overview. The generalized pattern of distribution for the subject chlorinated hydrocarbon solvents in British Columbia is shown in Figure 3.1.1. The figure traces the distribution of these solvents from the point of manufacture to the ultimate user. The primary distribution path is shown by the bold arrows and the arrow width is proportional to the total quantity of solvents involved at each step in the distribution. Minor distribution paths are indicated by line arrows. Activities within and outside of the province are distinguished by the dotted boundary line.

All of the subject solvents are shipped in bulk by tank truck or rail car from out-of-province manufacturers to a few major distributors located in the Lower Mainland. These distributors act as the primary source of supply for industrial clients which can be classed in three major categories:

- o Product Formulators - those companies which incorporate solvents into formulated products for distribution to other end users (e.g. packaged adhesives or paint strippers for the domestic market),
- o Industrial End Users - those companies which use the solvents directly in their manufacturing, service or maintenance activities (e.g. degreasers of metal parts),
- o Dry Cleaners - companies which use solvent directly in the dry cleaning of fabric or clothing for commercial or household markets.

Product Formulators manufacture a wide variety of commercial products which can, in turn, be categorized according to their intended End User:

TABLE 3.1.1

PRIMARY MANUFACTURERS AND DISTRIBUTORS OF CHLORINATED SOLVENTS IN BRITISH COLUMBIA

Solvent	Manufacturers	Distributors	Supply Quantity
Perchloroethylene	DOW*	Harrisons & Crosfield (Canada) Ltd. Van Waters & Rogers Ltd. Canada Colors and Chemicals Ltd.	Bulk, 45 gallon drums Bulk, 45 gallon drums Bulk, 45 gallon drums
	C-I-L*	C-I-L Inc.	Bulk, 45 gallon drums
	Various	Tessler Bros. Ltd.	Bulk
	?	B.C. Specialties	?
Methylene chloride	DOW*	Harrisons & Crosfield (Canada) Ltd. Van Waters & Rogers Ltd. Canada Colors and Chemicals Ltd.	Bulk, 45 gallon drums Bulk, 45 gallon drums Bulk, 45 gallon drums
	C-I-L*	C-I-L Inc.	Bulk, 45 gallon drums
	?	Chemcentral Ltd.	45 gallon drums
1,1,1-Trichloroethane	DOW*	Harrisons & Crosfield (Canada) Ltd. Van Waters & Rogers Ltd. Canada Colors and Chemicals Ltd.	Bulk, 45 gallon drums Bulk, 45 gallon drums Bulk, 45 gallon drums
	C-I-L*	C-I-L Inc. Canadian Hanson Ltd.	Bulk, 45 gallon drums 5 gallon pails only
Trichloroethylene	DOW*	Harrisons & Crosfield (Canada) Ltd. Van Waters & Rogers Ltd. Canada Colors and Chemicals Ltd.	Bulk, 45 gallon drums Bulk, 45 gallon drums Bulk, 45 gallon drums
	C-I-L*	C-I-L Inc. Canadian Hanson Ltd.	Bulk, 45 gallon drums Bulk, 45 gallon drums
	Allied Chem PPG & Others	Baron-Blakeslee ^o	45 gallon drums

* The Company has eastern Canadian production facilities for the indicated solvent

^o Solvent is supplied directly from U.S.-based offices

- o Industrial Products include all formulations which are specifically intended for use by Industrial End Users in their manufacturing, service or maintenance activities (e.g. adhesive use for label fixation by manufacturers); in contrast,
- o Consumer Products include formulations intended for Household End Users. In the context of this study, household use includes all uses by individuals outside of an industrial setting.

3.1.2 Manufacturers. Table 3.1.1 summarizes the major manufacturers and distributors which supply the subject chlorinated solvents to users in British Columbia. All of the chlorinated hydrocarbons under study are manufactured out-of-province. Dow Chemical Canada Inc. and C-I-L Inc. supply most of the total quantity of the subject chlorinated hydrocarbon solvents used in British Columbia (see Table 3.1.1). These two companies have the only Canadian facilities for manufacturing certain of the subject solvents. Dow Canadian production is marketed in Eastern Canada and solvent used in B.C. is primarily supplied from U.S. production. Dow services B.C. from U.S. production shipped via terminal facilities in Vancouver, Washington. Some perchloroethylene is supplied from Canadian production. All C-I-L Inc. solvents are formulated in Shawnigan, Quebec.

Several other companies manufacture chlorinated hydrocarbon solvents in the United States and import through distributors to the Canadian market. These companies were identified in the "Nationwide Quantity/Location Inventories for Chlorinated and Aromatic Hydrocarbons" completed in 1979 by Acres Consulting Services Ltd. for Environment Canada. All of the companies identified in the Acres Inventory are primarily active in the Eastern Canadian market. Solvents from U.S. based manufacturers (other than Dow) only have a small share of the total market.

3.1.3 Distributors. The primary distributors of chlorinated solvents in B.C. are summarized in Table 3.1.1. Dow products are primarily marketed by appointed distributors, whereas C-I-L generally provides distribution for its own products. The bulk of the chlorinated hydrocarbon market in B.C. is currently supplied (for Dow products) by Van Waters and Rogers, Harrisons and Crosfield (Canada) Ltd., Canada Colors and Chemicals Ltd. (to a lesser extent), and (for

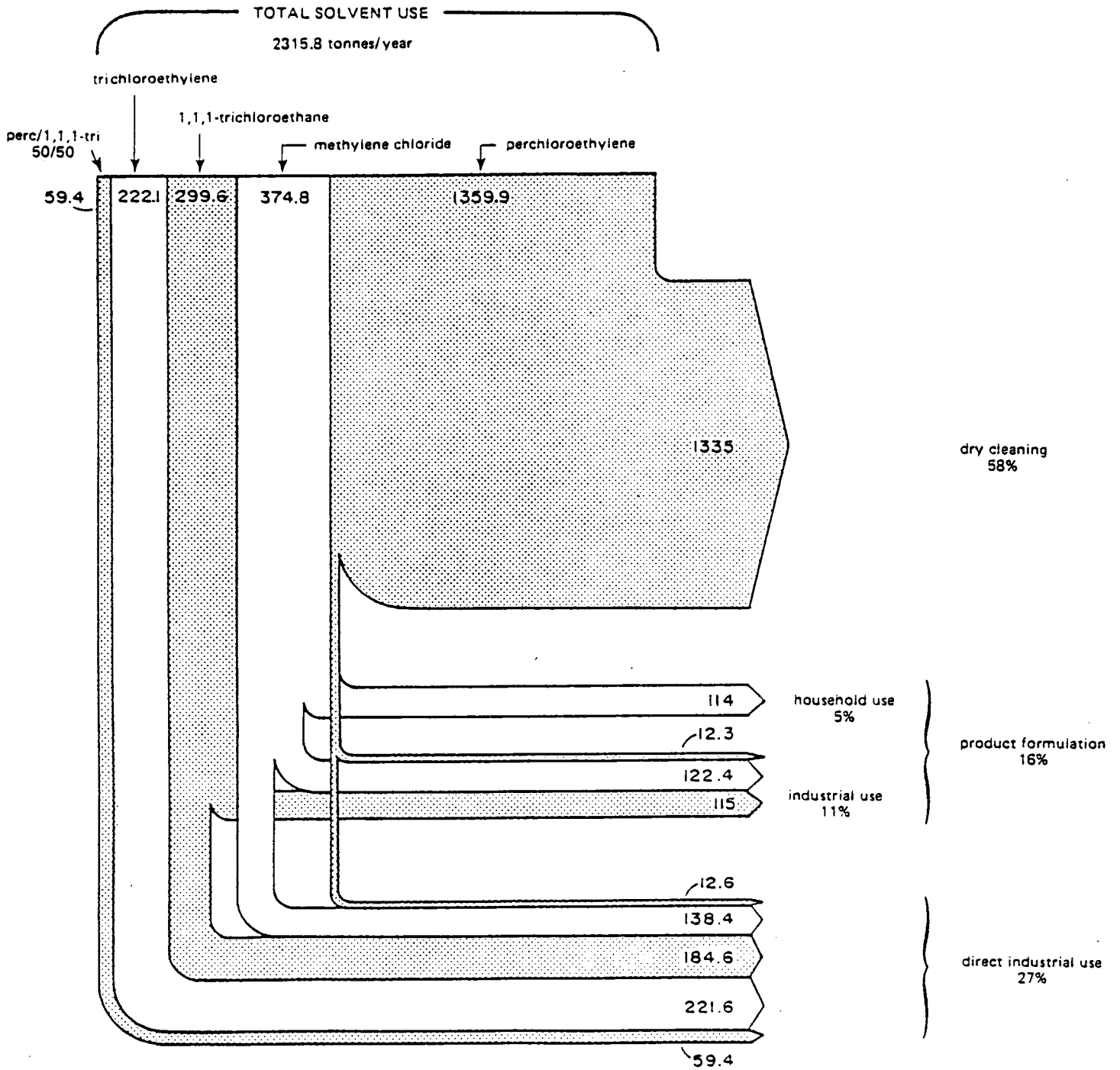


FIGURE 3.1.2: CATEGORIES OF USE FOR CHLORINATED HYDROCARBON SOLVENTS IN BRITISH COLUMBIA.

C-I-L products) by C-I-L. C-I-L degreasing solvents are also distributed to the B.C. market by Canadian Hanson Ltd., a specialized chemical equipment supply company which is a subsidiary of C-I-L. Some of the other distributors listed purchase solvents on a "spot market" for subsequent distribution to their customers.

All of the primary distributors service the market from distribution facilities located in B.C. As noted in Section 3.1.2, a relatively small portion of the total market is supplied by distributors based in the United States.

3.1.4 Quantities of Solvent Use in B.C. A total of 2315.8 tonnes of the subject chlorinated solvents was supplied to the B.C. market in 1981 via the major distribution pathways identified in Figure 3.1.2. Figure 3.1.2 describes the distribution of these solvents by specific solvent type (perchloroethylene, methylene chloride, 1,1,1-trichloroethane and trichloroethylene) and by the general category of user (product formulator, industrial end user and household end user).

The quantitative description of general solvent use patterns is based on 1981 data obtained from major B.C. distributors of the subject solvents. The smallest quantity of use reported by individual users was 0.1 tonne/year. The information is subject to the uncertainties inherent in market forecasting in a dynamic industry and the data should be interpreted as reasonable indicators of solvent use rather than as precise quantities of actual use.

1981 is the most recent year for which complete data could be obtained. Furthermore, solvent demand by many large volume users was atypically low in 1982. Depressed economic conditions in British Columbia during 1982 reduced production resulting in an estimated overall drop in chlorinated solvent consumption of which ranged from 15 to 60% depending on the solvent. 1981 solvent consumption is considered to be more representative of typical solvent consumption by industry in B.C.

3.1.4.1 Use by Solvent Type. Perchloroethylene use in 1981 by the dry cleaning industry was 1335 tonnes and this represented 58% of the total subject chlorinated hydrocarbon use in British Columbia. Perchloroethylene is supplied

directly to dry cleaning shops by distributors and only relatively small quantities of perchloroethylene (an additional 2% of the total perchloroethylene market) are used for product formulation or other industrial purposes.

Methylene chloride use in British Columbia during 1981 was 374.8 tonnes, representing 16% of the total chlorinated solvent use. This solvent is distributed approximately equally between industrial end users, formulators whose products serve an industrial market, and formulators of products intended for household use.

In 1981, 1,1,1-trichloroethane use in British Columbia was 299.6 tonnes, representing 13% of the chlorinated solvent market. Approximately two-thirds of 1,1,1-trichloroethane used in B.C. is consumed directly by industrial end users and the balance is used by formulators in products directed at the industrial market.

Trichloroethylene use in British Columbia was 222.1 tonnes, representing 10% of total chlorinated solvent use. Virtually all trichloroethylene is used directly by industrial end users.

Industrial end users directly consumed an additional 59.4 tonnes in 1981 of perchloroethylene and 1,1,1-trichloroethane which is supplied by distributors as a 50/50 mixture. This mixture represents approximately 3% of the total market for the subject solvents.

3.1.4.2 Use by Category of End User. Figure 3.1.2 also shows the distribution of chlorinated solvents in B.C. according to the general user category. The use of perchloroethylene by the dry cleaning industry represents 58% of the total consumption of the subject solvents. An additional 27% of the total market is represented by industrial end users who consume the solvents directly in their activities. Companies which formulate products for industrial users consume 11% of the subject solvents, and the remaining 5% is consumed by formulators whose products enter the consumer market for household end users.

As shown in Figure 3.1.1, some formulated products are supplied to industrial and household end users from processing firms located outside of British Columbia. Similarly, some formulated products manufactured in British Columbia are exported to users outside of the province. The quantity of subject solvents contained in these imports and exports of formulated products may be as much as several hundred tonnes/year, representing a significant percentage of the total quantity of chlorinated solvent use shown in Figures 3.1.1 and 3.1.2. Section 3.2.6 provides additional discussion on the formulated product industry. The precise quantity of solvent contained in imported and exported products could not be determined because of the following factors:

- o consumer products are handled by a large number of retail outlets;
- o retailers cannot identify specific products containing the subject solvents and formulated products containing these solvents generally do not list specific ingredients;
- o some formulations are considered to be proprietary and product formulators in B.C. would not divulge quantitative information on the composition and marketing of these products.

3.1.4.3 Use by Specific End User Application. The detailed use pattern for the subject chlorinated solvents purchased in British Columbia is shown in Figure 3.1.3 and Table 3.1.2. The table summarizes and defines the various use applications for each solvent and summarizes the annual quantity of each solvent utilized by industrial companies in each category of use. The number of companies identified in each category is also indicated.

The table is organized according to solvent type and subdivided according to end user type. Specific solvent applications are used to characterize additional subdivisions within each type of end user. For example, methylene chloride is used by product formulators and industrial end users. The 29 industrial end users are classed in eight solvent application groups. The application group which uses the most methylene chloride is made up of ten firms which fabricate metals doors and windows. These firms use the solvent for the cleanup of mastic sealant applicators.

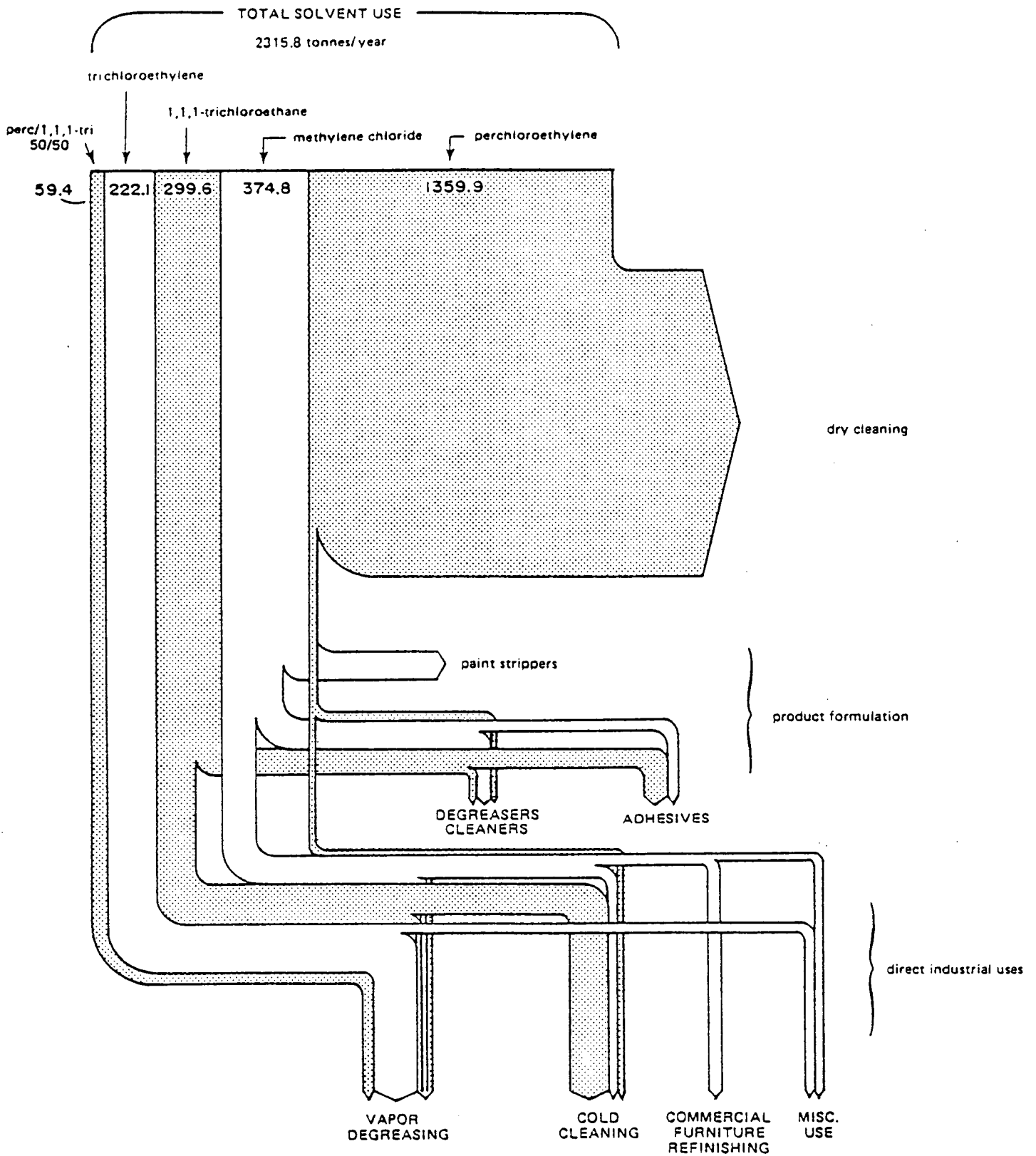


FIGURE 3.1.3: END USES OF CHLORINATED HYDROCARBON SOLVENTS IN BRITISH COLUMBIA.

TABLE 3.1.2 CHLORINATED HYDROCARBON SOLVENT USE IN BRITISH COLUMBIA

Solvent	End User Category	End User or Product	Number of Users	Specific Application	Quantity of Solvent tonnes/year		
Perchloroethylene	Dry Cleaners	Dry Cleaners	(800)	Cleaning Solvent (Fabrics)	1335	(1335)	
	Product Formulators						
	Industrial Products	Degreasers Analytical Degreasers	(1) (1)		12 0.3	(12.3)	
	Industrial End Users	Electronic Eqt. Mfg.	(1)	Vapor Degreasing: Elect. Components	9		
		Printing Shops	(1)	Equipment Cleanup	3		
		Vehicle Maint. Shops	(2)	Vapor Degreasing: Vehicle Parts	0.6	(12.6)	
	All Categories			Perchloroethylene Total		1359.9	
	Methylene Chloride	Product Formulators					
		Household Products	Paint Strippers	(5)		114	
		Industrial Products	Degreasers, Cleaners	(3)		68	
Adhesives, Glues			(2)		51.4		
Inks			(1)		3	(236.4)	
Industrial End Users		Metal Window, Door Mfg.	(10)	Cleanup: Mastic Sealant	37.5		
		Furniture Refinishers	(2)	Furniture Stripping	35		
		Plastic Prod. Rfrs.	(1)	Bonding Recoated Surfaces	30		
		Foamed Plastic Products Mfg.	(4)	Foam Head Cleanup	14.6		
		Shops Supporting Mfg.*	(8)	Vapor Degreasing: Equipment	12		
		Electroplaters	(2)	Vapor Degreasing: Metal Prod.	8		
		Electrical Eqt. Mfg.	(1)	Vapor Degreasing: Elect. Components	1		
		Materials Testing Lab	(1)	Asphalt Testing	0.3	(138.4)	
		All Categories			Methylene Chloride Total		374.8

TABLE 3.1.2 (Page Two)

Solvent	End User Category	End User or Product	Number of Users	Specific Application	Quantity of Solvent tonnes/year		
1,1,1-Trichloroethane							
Cold Cleaning Inhibitor Formula	Product Formulators Industrial Products	Adhesives	(3)		100		
		Cleaners	(3)		15 (115)		
	Industrial End Users	Shops Supporting Mfg.*	(44)	Cold Cleaning: Equipment	104.7		
		Metal Products Mfrs.**	(18)	Cold Cleaning: Products	20		
		Vehicle Maint. Shops	(5)	Cold Cleaning: Vehicle Parts	13.1		
		Compressed Gas Mfrs.	(3)	Cold Cleaning: Cylinder Heads	4.9		
		Foamed Plastic Products Mfrs.	(1)	Cold Cleaning: Foam Heads	4		
		Motion Picture Film Labs	(2)	Film Cleaning	3.3		
		Printing Shops	(1)	Equipment Cleanup	1		
		Analytical Labs	(2)	Miscellaneous	0.4 (151.4)		
		All Categories				1,1,1-Trichloroethane Total	299.6
		Vapor Degreasing Inhibitor Formula	Industrial End Users	Shops Supporting Mfg.*	(5)	Vapor Degreasing: Equipment	17
				Metal Product Mfrs.**	(4)	Vapor Degreasing: Metal Prod.	5.1
Vehicle Maint. Shops	(4)			Vapor Degreasing: Vehicle Prts	10.1		
Motion Picture Film Labs	(3)			Film Cleaning	1 (33.2)		
All Categories				1,1,1-Trichloroethane Total	299.6		
Trichloroethylene	Product Formulator Industrial Products		Miscellaneous	(1)		0.5 (0.5)	
		Industrial End Users	Shops Supporting Mfg.*	(4)	Vapor Degreasing: Equipment	4.1	
	Plywood Mfrs.		(1)	Ingredient in Wood Filler	25		
	Metal Products Mfrs.**		(6)	Vapor Degreasing: Metal Prod.	110		
	Electroplaters		(1)	Vapor Degreasing: Metal Prod.	13		
	Electronic Eqt.Mfrs.		(2)	Vapor Degreasing: Elect. Components	14		
	Vehicle Maint. Shops						
	Rail		(1)	Vapor Degreasing: Vehicle Prts	38		
	Air		(1)		16		
	Truck		(1)		1.5 (221.6)		
	All Categories				Trichloroethylene Total	222.1	

TABLE 3.1.2 (Page Three)

Solvent	End User Category	End User or Product	Number of Users	Specific Application	Quantity of Solvent tonnes/year
Perc/1,1,1-Tri 50/50 Mixture	Industrial End Users	Shops Supporting Mfg.* (1)		Vapor Degreasing: Equipment	13
		Metal Products Mfrs.** (2)		Vapor Degreasing: Metal Prod.	15.4
		Vehicle Maint. Shops (2)		Vapor Degreasing: Vehicle Prts	31
		All Categories		Perc/1,1,1-Tri	
			All Solvents Total		2315.8

*Solvent used by equipment maintenance shops supporting manufacturing activities
 **Solvent used directly in cleaning or preparing the manufactured product

The Standard Industrial Classification (S.I.C.) system has not been used to characterize industrial end users or formulators. The subject solvents are used by at least one industry in nearly every primary S.I.C. category, and the use of chlorinated solvents is often motivated by user-specific requirements which are difficult to predict from the assigned S.I.C. numbers. The specific solvent application categories used in Table 3.1.2 provide a more meaningful grouping of users according to the activity associated with the actual use of the given solvent. These categories can be used to identify specific types of industrial operations which are potential users of chlorinated solvents.

3.1.5 Trends of Solvent Demand. The demand for chlorinated solvents is dynamic and depends strongly on economic factors. Overall solvent demand is tied to production and total solvent consumption falls during hard times. It is estimated that the total consumption of certain chlorinated solvents in 1982 fell as much as 60% relative to 1981. This reflects the significant reduction in activity by many B.C. firms during 1982. The least affected solvent was perchloroethylene, because dry-cleaners were less susceptible to economic conditions.

Solvent demand by specific users is greatly influenced by solvent cost. Within the bounds of technical and service requirements, users seek out least cost options. The solvent market is highly competitive and many users will readily change solvents and/or suppliers in order to reduce costs.

Subject to the above comments, the anticipated demand trends for specific solvents in B.C. are as follows:

3.1.5.1 Perchloroethylene. Virtually all perchloroethylene sold in British Columbia is used by the dry cleaning industry. There is no indication that competing solvents will enter the market in the foreseeable future. The industry demand for solvent is essentially proportional to population and no significant change in solvent consumption is currently anticipated for the market in British Columbia.

3.1.5.2 Methylene Chloride. The primary market for methylene chloride is as a base solvent in formulated paint strippers and industrial cleaning products. Methylene chloride is highly effective as a paint stripper and replacement by other solvents for this application is not likely. Suppliers project that the total consumption of methylene chloride in British Columbia is increasing at about 5% per year.

3.1.5.3 1,1,1-Trichloroethane. This solvent serves a diverse range of industrial uses including cold metal cleaning, vapor degreasing and use as a carrier solvent in adhesive and coating formulations. Suppliers have projected that the total consumption for 1,1,1-trichloroethane is growing at about 8% per year.

3.1.5.4 Trichloroethylene. Trichloroethylene is primarily used for industrial metal cleaning applications. Perceived environmental and worker safety concerns have generally caused a decline in Canadian and U.S. production of this solvent since 1970. Suppliers have projected that the annual consumption of trichloroethylene in British Columbia is steady to declining. Suppliers have also claimed that the B.C. metal cleaning industry is showing a trend away from the use of trichloroethylene in favour of 1,1,1-trichloroethane. This trend is motivated by lower operating costs and a higher permissible workplace concentration for 1,1,1-trichloroethane. In spite of this trend, at least one major distributor of solvents in B.C. generally promotes trichloroethylene as the most effective solvent for use in vapor degreasers. Furthermore, several users indicated that 1,1,1-trichloroethane was not as effective for degreasing as was trichloroethylene. One large user was experimenting with the use of freons as replacements for trichloroethylene.

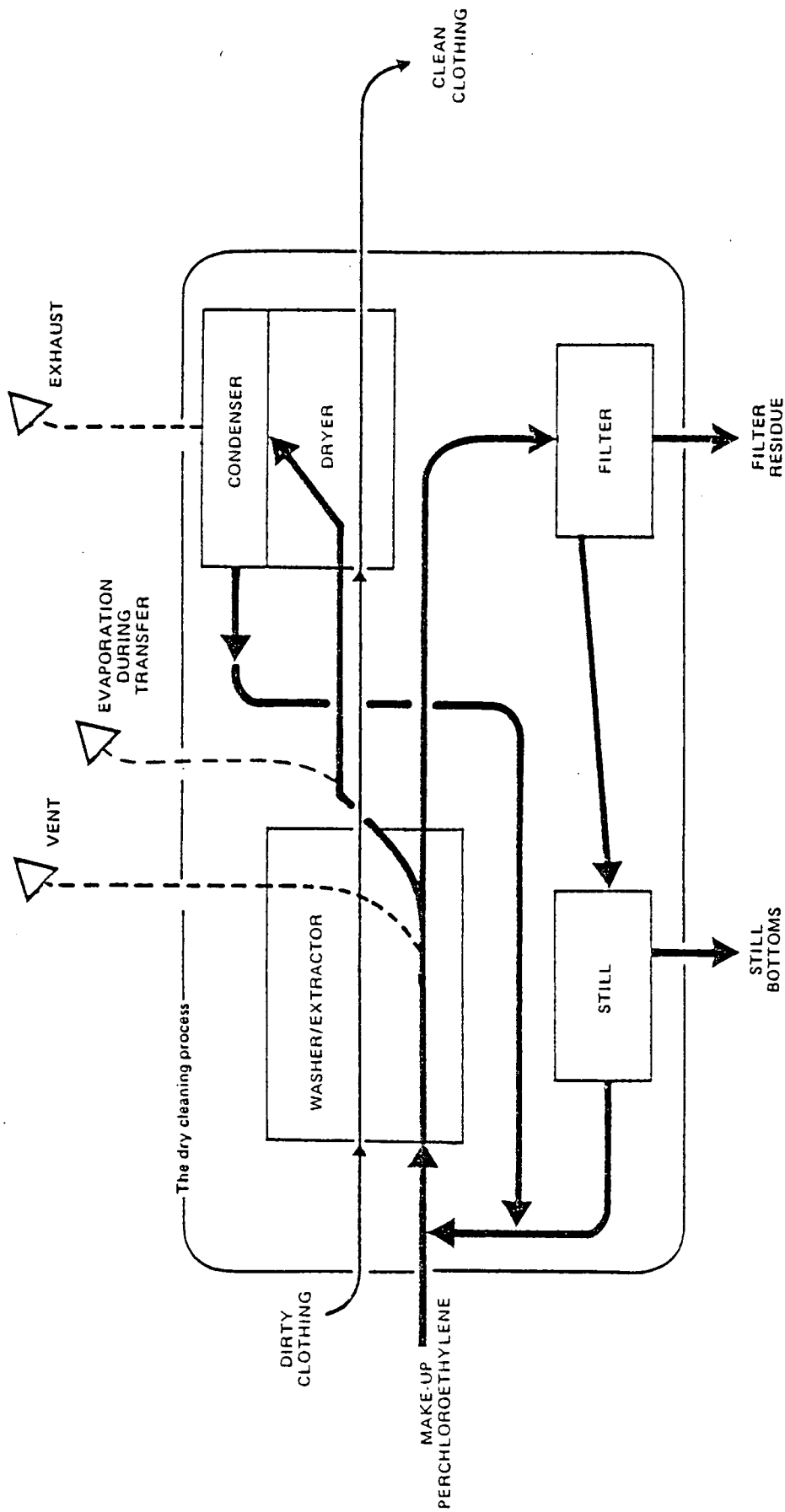


FIGURE 3.2.1 : PERCHLOROETHYLENE FLOW IN THE DRY CLEANING OF CLOTHING.

3.2 Solvent Use Practices in B.C.

3.2.1 Dry Cleaning

3.2.1.1 Process Description. A simplified conceptual diagram of the traditional, commercial dry cleaning process is shown in Figure 3.2.1. The description of the process is considered in terms of the flows of clothing and liquid solvent through the various dry-cleaning operations. Perchloroethylene (tetrachloroethylene) is used exclusively in dry cleaning plants in British Columbia.

3.2.1.1.1 Clothing Flow. The dry cleaning of clothing with solvent is analogous to conventional laundering in a home washer/dryer with the added feature of washing fluid recycle. The clothing is first washed with the perchloroethylene solvent in an agitated washer. The clothing is then spun to extract the free solvent and tumbled dry during a heated drying cycle. The drying cycle concludes with the venting of ambient air through the clothing ("aeration or deodorization") to remove the final traces of solvent.

There are two common variations of equipment configuration related to the flow of clothing through the process. Dry-to-dry or "hot" equipment integrates all operations into a single machine unit. Transfer machines normally combine washing/extraction in one unit and require a transfer to a separate drying machine.

3.2.1.1.2 Liquid Solvent Flow. Perchloroethylene is added to the clothing in the washer. Smaller quantities of water and detergent are charged to the solvent as additives to remove water soluble dirt from the clothing during the washing step. The washing solvent is removed from the clothing during the subsequent centrifugal extraction. Discharged solvent contains insoluble dirt and oils, fats and greases which were removed from the clothing during the wash.

The recycling process for the dirty liquid solvent from the washer consists of filtration (to remove solids) followed by distillation (to remove non-volatile oils, fats and greases).

3.2.1.1.3 Filtration. Two types of filters are commonly used. The oldest type uses an inert diatomaceous earth filter powder to remove solids. The resulting dirty filter medium ("muck") is usually heated or "cooked" to reclaim residual solvent before the muck is discarded and replaced with fresh diatomaceous earth.

The second and more modern filter type consists of a fluted paper cartridge which may contain a carbon core. There are numerous variations of cartridge filters in common use. Modern cartridge filters have a high absorptive capacity for non-filterable oils and greases in the dirty solvent and this has eliminated the use of solvent stills by many operators. Spent cartridges are normally drained of solvent prior to disposal and individual operators utilize a variety of innovative techniques to maximize the recovery of residual solvent.

3.2.1.1.4 Distillation. When non-absorptive filters are used, the non-volatile substances in the filtered solvent are removed in a solvent still. The distilled solvent is then returned to a holding tank for reuse as a fresh dry cleaning fluid. The bottom residue from the still contains water, residual solvent, the fats, oils and greases removed from dirty clothing, and filter powder carried over from diatomaceous earth filters.

3.2.1.1.5 Points of Solvent Emission. Solvent vapor is emitted at several points in the dry cleaning process and the extent of vapor recovery varies considerably with the specific type of process equipment and recovery practices which are used. The major points of solvent loss and vapor emission from transfer equipment (utilizing a separate dryer) are shown in Figure 3.2.1 and include:

- o residual solvent in the filter muck or filter cartridge,
- o residual solvent in the still bottoms,
- o exhaust gas from the washer/extractor,
- o exhaust gas from the dryer,
- o losses from clothing during transfer from the washer/extractor to the dryer, and
- o miscellaneous losses of solvent from pumps, valves, flanges, seals, solvent-water separators and inefficient handling practices.

Solvent losses from several of these routes are reduced or eliminated with more modern equipment. Clothing transfer losses are eliminated with the unit dry-to-dry equipment. Losses from the distillation process are eliminated by equipment which utilizes absorptive filter cartridges (thereby eliminating distillation). Finally, solvent losses from exhaust vents can be significantly reduced using vapor recovery equipment described in the following section.

3.2.1.1.6 Solvent Recovery Systems. It is normal practice to recover solvent from the dryer exhaust of older machines by means of a water-cooled condenser (see Figure 3.2.1). More modern installations achieve additional vapor recovery by using an activated carbon adsorber ("sniffer") to reduce the solvent level in exhaust vapors from the dryer gas condenser, the extractor vent and the still condenser. Solvent is then recovered from the carbon adsorber during a desorption cycle.

The most advanced, state-of-the-art equipment operates in a closed circuit and completely eliminates solvent-laden exhaust streams. The equipment is tightly sealed during operation to minimize solvent vapor losses. Highly-efficient refrigerated condensers extract solvent from recirculated air during the deodorization of clean clothing.

3.2.1.2 Quantities of Solvent Emissions

3.2.1.2.1 Total Solvent Emissions. Table 3.2.1 compares estimates of total plant emissions of perchloroethylene for different industry sectors and degrees of control. Total emissions are generally the order of 10 kg solvent/100 kg clothing processed, and range as low as 1.8 kg solvent/100 kg clothing for carefully controlled operations using modern equipment.

The information in Table 3.2.1 is compiled from several extensive studies of perchloroethylene emissions from dry cleaning plants located in the United States and elsewhere (U.S. EPA, 1980; U.S. EPA, 1973; U.S. EPA, 1974; Great Britain Department of the Environment, 1976). No systematic survey has been undertaken to determine total solvent emissions from individual dry

TABLE 3.2.1 TOTAL PERCHLOROETHYLENE EMISSIONS FROM DRY CLEANERS

Dry Cleaning Plant Type	Emissions Control	Perchloroethylene Emissions kg/100 kg Clothing	Reference
<u>B.C. Industry</u>			
Commercial Sector Dry-to-Dry, Cartridge Filter	Average Operation	8.0 to 9.0	D. Willis, 1982
State-of-the-art Equipment (Refrigerated Condensers)	Above-average Operation	2.4 to 2.6	
State-of-the-art Equipment (Refrigerated Condensers)	Unverified Claim by Operator	1.8	
Calculated Consumption Based on Total Actual Industry Consumption of Solvent	(1335 tonnes/year) x(2.5 million people in B.C.) x(8.2 kg clothing cleaned per person per year)	6.5	-
<u>U.S. Industry</u>			
Coin-Op Sector (5% of all Plants controlled)	Uncontrolled Controlled Sector Average	15.9 11.3 15.7	
Commercial Sector (35% of all Plants controlled)	Uncontrolled Controlled Sector Average	10.1 8.4 9.5	U.S. EPA, 1980
Industrial Sector (50% of all Plants controlled)	Uncontrolled Controlled Sector Average	11.4 9.5 10.4	

Table 3.2.1 (Page Two)

Dry Cleaning Plant Type	Emissions Control	Perchloroethylene Emissions kg/100 kg Clothing	Reference
Average Plant		Average 13.6 per day Maximum 31.8 per day	
Small Neighborhood Plant Separate Washer/ Extractor and Dryer.		10 to 15	U.S. EPA, 1973
Dry-to-Dry (Single Machine)		4.9 to 7.5	
Coin-Op (Dry-to-Dry)		15 to 49	
	Uncontrolled	10.5	
	Average Control	4.8	U.S. EPA, 1975
	Good Control	1.8	

cleaning plants in British Columbia. The estimates in Table 3.2.1 for total perchloroethylene emissions from B.C. operations were obtained in discussions with equipment and solvent suppliers.

3.2.1.2.2 Unit Process Emissions. There have been no systematic studies to determine solvent emissions from unit processes in dry cleaning plants in British Columbia. Quantities of filter residues have been estimated in surveys of industrial and toxic wastes generated by dry cleaners in Vancouver and in the Greater Vancouver Regional District (G.V.S. and D.D., 1978; EPS, 1979).

The U.S. Environmental Protection Agency (1980) presents data characterizing emissions from each process step for well-operated facilities using a vapor condenser on the dryer exhaust. This information is presented in Table 3.2.2, which shows emissions for three common filter configurations:

- o a rigid tube diatomaceous earth filter with no muck cooker,
- o a regenerative diatomaceous earth filter with residual solvent reclaim in a muck cooker, and
- o filtration with paper cartridges drained before disposal.

Table 3.2.2 also shows the additional recovery achieved by adding a carbon adsorber to treat exhaust vapors.

3.2.1.3 The Dry Cleaning Industry in B.C. The dry cleaning industry in British Columbia consists of three large commercial plants located in the Lower Mainland (servicing the industrial market) and an estimated 800 establishments servicing the residential dry cleaning market (B.C. Fabricare Institute -personal communication, 1983). The residential shops are approximately equally divided between the Municipalities of the Greater Vancouver Regional District and the balance of the province.

Information for the current assessment of B.C. industry was based on:

- o a review of the literature, including prior surveys of waste from dry cleaning shops in B.C. (EPS, 1979; G.V.S. and D.D., 1978),

TABLE 3.2.2 UNIT PROCESS PERCHLOROETHYLENE EMISSIONS FROM DRY CLEANERS (U.S. EPA, 1980)

Emission Source	Perchloroethylene Emissions ¹ kg/100 kg Clothing			
	A	B	C	D
Configuration ³				
Washer (Evaporation)	0.54	0.54	0.54	-
Dryer ² (Evaporation)	3.0	3.0	3.0	-
Vapor Adsorber Exhaust	-	-	-	0.3
Muck Retention				
No Cook	14.0	-	-	-
Cook	-	1.6	-	-
Cartridge				
Drained	-	-	1.8	-
Heated	-	-	-	1.2
Still Bottoms	1.6	1.6	1.6	1.6
Miscellaneous	2.0	2.0	2.0	2.0
TOTAL	21.14	8.74	8.94	6.1

¹All data from well-operated, well-controlled facilities (not the industry norm)

²A vapor condenser on dryer exhaust is assumed in all cases

³Configuration A: Rigid filter (diatomaceous earth), no cook
 Configuration B: Rigid filter (diatomaceous earth), cook
 Configuration C: Cartridge filter
 Configuration D: Cartridge filter, vapor adsorber on all vents

- o site visits to two residential dry cleaning shops whose operators have extensive experience and knowledge of the industry,
- o discussions with a major supplier of dry cleaning equipment and solvent (supplying an estimated 50% of the market).

Key information about perchloroethylene use by the dry cleaning industry in British Columbia is further discussed in Section 3.3. The industry can generally be characterized as being above the North American norm in terms of acceptance and use of modern equipment. The incidence of late-model machines is greater than elsewhere and it is estimated that 70% of the dry cleaning plants in B.C. employ dry-to-dry ("hot") machines (D. Willis, pers. comm., 1982). It is also estimated that 90% of B.C. dry cleaning plants employ cartridge filters.

In many cases, the use of absorptive filters has eliminated the use of solvent stills. Diatomaceous filter cartridges have been retained chiefly by large industrial cleaners. These plants now generally use two stills per cleaning machine, resulting in considerable improvement in distillation efficiencies.

3.2.1.4 Problem Areas. The major problem areas associated with dry cleaning operations are:

- o worker exposure to solvent vapor
- o disposal of spent filter media

The primary concern is worker exposure to excessive levels of solvent vapor at facilities which follow poor operating practices. Vapor levels at modern well-operated facilities are normally well below permissible levels. However poor operating practice can produce vapor concentrations in the workplace as much as 10 times the permissible levels. Exposure to excessive vapor levels is nearly always the result of faulty equipment or failure to follow routine good operating procedures. Workplace monitoring and technical expertise is readily available through equipment and solvent suppliers and most workplace problems in B.C. can be solved by utilization of these resources.

A secondary concern is the disposal of still bottoms or spent filter media (primarily filter cartridges in B.C.). The presence of residual perchloroethylene generally qualifies these materials as unsuitable for conventional landfill disposal. In reality, conventional landfill is the predominant disposal method used by most dry-cleaning shops in B.C. The high cost of solvent has motivated the use of several innovative techniques for reducing residual solvent in spent filters. Furthermore, the high volatility of perchloroethylene probably ensures that much residual solvent in wastes to landfill ultimately is lost to air. It is doubtful that the environmental impact of residual solvent disposal to conventional landfill is of significance under normal circumstances.

3.2.2 Vapor Degreasing

3.2.2.1 Process Description. Vapor degreasing is widely used in industry to remove oil, oil-borne soil or flux from metal parts. There are numerous variations of degreasing equipment, however the basic process is essentially the same: cold metal parts are immersed in a hot solvent vapor which condenses on the metal surface and flushes oils away as the solvent drains from the parts. Figure 3.2.2 illustrates the basic features of two types of degreasing units commonly used by industrial operations in British Columbia. One unit type consists of an open-topped tank with heating coils located near the floor and condensing coils positioned around the walls near the top. A small amount of solvent (usually a few centimeters deep) is contained in the tank and heated and vaporized by the heating coils. Common degreasing solvents have vapors heavier than air so that they can be contained in the tank. The dense vapors rise to fill the work zone between the boiling liquid and the condensing coils. As the vapor contacts the cooling coils, it is condensed and returned to the boiling liquid sump.

The work pieces are suspended in a basket which is lowered into the layer of pure condensing solvent vapor which condenses on the work surfaces. The solvent dissolves and washes away contaminants as it drains back into the degreaser tank. When the surface temperature of the work pieces reaches that of the solvent vapor, condensation ceases and the clean, dry work is withdrawn.

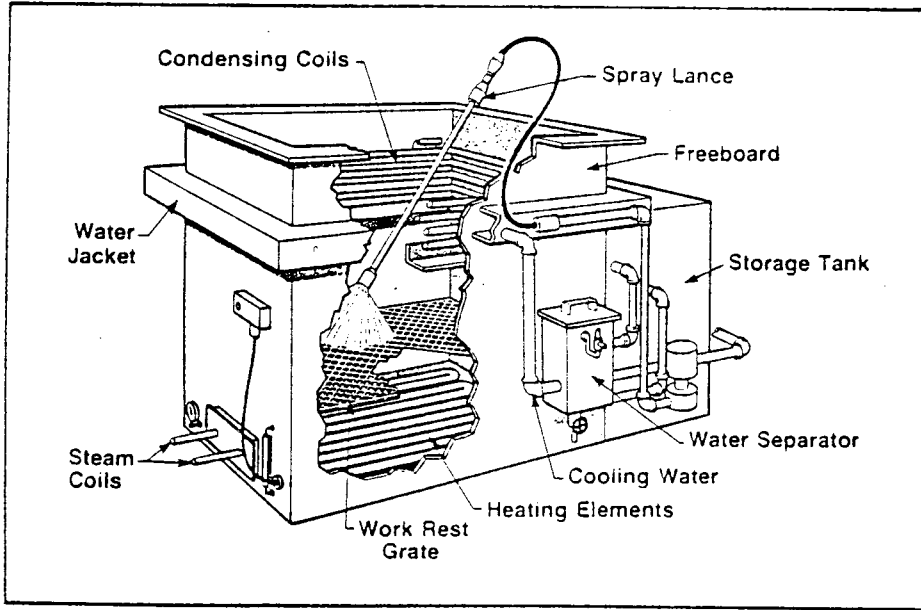


FIGURE 3.2.2a : VAPOR DEGREASER WITH SPRAY ATTACHMENT.

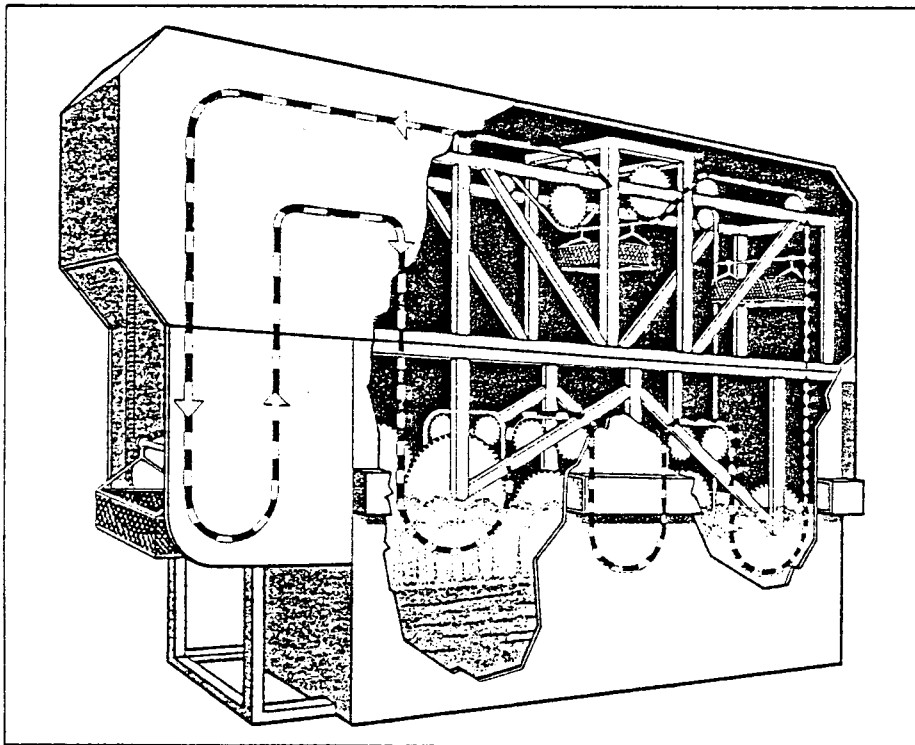


FIGURE 3.2.2b : CROSS-ROD CONVEYORIZED DEGREASER.

FIGURE 3.2.2: TYPICAL VAPOR DEGREASING EQUIPMENT.

The degreaser unit shown in Figure 3.2.2 (a) is equipped with a spray lance. This allows heavily contaminated parts to be flushed with clean cool solvent and lowers the surface temperature of the work to enable further vapor condensation. The unit shown in the figure is representative of the batch manual degreasers used by many industrial operations. Small work pieces are normally contained in a metal mesh basket which is lowered into the work zone until cleaning is complete.

Large production operations may utilize larger enclosed and conveyorized degreasers which continuously transport the work baskets through the unit as illustrated in Figure 3.2.2 (b). The numerous variations of degreasing equipment are illustrated and described in detail in technical literature which is available from solvent suppliers such as Dow Chemical. Figure 3.2.2 was obtained from Dow Chemical literature.

3.2.2.2 Equipment Features and Safeguards. Modern degreasers incorporate several basic features which are important to safe and efficient operation. Degreasers manufactured in recent years are equipped with these safeguards as standard features. Older units can and should be retrofitted with any of these safeguards which are lacking.

a. Heat Source Regulation

The heat source must provide controlled energy release to vaporize the solvent. Precautions must be taken to avoid superheating, exposure of the heating elements, or hot spots which can lead to solvent decomposition and burnout of the heating element. Steam, electricity and gas are all used as energy sources, although steam is preferred because of the effective control of temperature which can be achieved by pressure regulation. Regardless of heat source, safety shut-off mechanisms should be installed and linked to:

- o vapor thermostats, to shut off the heat supply if the vapor level rises above the condenser coils,
- o solvent thermostats, to shut off the heat supply if the liquid solvent temperature exceeds safe limits,

- o float switches, to shut off the heat supply if the solvent level drops below a certain level;
- o interlock mechanisms to ensure that the heat supply cannot be turned on unless the condenser water is flowing.

b. Vapor Control

The condenser coils must be designed to allow clearance below the work and a vapor layer above the work. Temperatures must be regulated to avoid excessive condensation.

c. Freeboard

Freeboard is the zone between the upper vapor level and the tank top. Sufficient freeboard must be provided to allow proper drainage and evaporation of residual solvent from work being removed. Adequate freeboard protects against vapor disturbances from air motion in the work area and minimizes solvent losses from the degreaser tank.

d. Water Separation

A properly-sized water separator is essential to remove water which is condensed with the solvent vapor. Water buildup in the condensed solvent causes corrosion of equipment surfaces and shortens the solvent life.

e. Tank Covers

Open-top tank vapor degreasers should be provided with covers to minimize vapor losses during periods of idling. Large units are frequently fitted with hinged covers which can be closed during the cleaning cycle.

3.2.2.3 Solvent Reclamation. Oil and dirt removed from the work pieces eventually accumulates to an unacceptable level in the degreaser solvent. Many large degreasing systems utilize an external solvent still to separate the solvent from these non-volatile contaminants. The recovered solvent is returned to the degreaser and the still bottoms are disposed of. When stills are not available,

the degreaser unit itself may be used to concentrate dirty solvent prior to cleanout. Some users ship dirty solvent to off-site (out-of-province) reclaimers for recovery of the solvent.

3.2.2.4 Points of Solvent Loss. Solvent consumption in vapor degreasing operations can be categorized as follows:

- o replacement of solvent which has reached the unacceptable limit for contamination or decomposition, and
- o evaporative losses.

3.2.2.4.1 Replacement. Degreaser solvents must be replaced with fresh solvent when the level of soil elevates the boiling point of the solvent beyond the acceptable limit (generally at a soil concentration of about 30%). Operation at high levels of contamination results in decreased cleaning efficiency, poor vapor generation, sludge formation and fouling of the heating element.

Solvent life will be diminished if the degreaser is operated with fouled or exposed heating elements. This creates hot spots which accelerate the chemical decomposition of the solvent. Decomposition creates an acidic condition due to formation of hydrochloric acid. Stabilizer additives protect the solvent from acid production under normal circumstances. If these stabilizers are lost, an acidic condition will occur and the solvent must be replaced. Other decomposition products include phosgene and peroxy-compounds, the latter being potentially explosive (Fuller, 1976).

3.2.2.4.2 Evaporation. Evaporation losses from a poorly-operated degreaser can be substantial. The major points of evaporative loss include:

- o losses of vapor through the open tank surface during idling (failure to use a tank cover),
- o losses of vapor through the open tank surface during entrance and exit of the work pieces (especially when the rated capacity or travel speed is exceeded),
- o "dragout" losses of residual liquid on work pieces,

- o losses of vapor through the open tank surfaces while the work is in the vapor zone (where use of a cover is not practical),
- o boilover of vapor from improper functioning of heaters or condensers,
- o loss of vapor from the tank surface caused by inadequate freeboard and/or motion of the room air.

Any or all of the listed items can contribute significantly to the total consumption of solvent. The relative contribution of these factors to losses from a specific degreaser depends strongly on the design of the equipment and the manner in which it is operated.

In addition to the solvent losses listed above, evaporation losses also can occur during the following operations:

- o transfer of solvent from storage tanks or drums to the degreaser unit,
- o on-site distillation to recover dirty solvent,
- o storage of still bottoms and cleanout sludges pending disposal.

3.2.2.5 Quantities of Solvent Loss

3.2.2.5.1 Total Process Emissions. When on-site reclamation of dirty solvent is practiced, the total on-site emissions of solvent vapor from degreasing operations are approximately equal to solvent purchases. Still bottoms and sludges from these operations are commonly stored on-site in open containers pending disposal. Most residual solvent is lost to the atmosphere prior to disposal of the sludge off-site.

Users of small degreaser units, users with no distillation equipment, or users requiring high purity solvent (e.g. manufacturers of electronic components) may transport dirty oil-solvent mixtures off-site for reclaim or disposal. On-site emissions of solvent vapor from these users is approximately 50 percent of solvent purchases. In such cases, the volume of dirty solvent mixture sent for reclaim may be of the order of 70% of clean solvent use. Allowing for 30 percent soil, the dirty solvent mixture contains about half of the original clean solvent. The balance is lost on-site as evaporative emissions.

3.2.2.5.2 Unit Process Emissions. The rate of vapor loss from an idling degreaser has been determined by a solvent supplier (Dow, 1981) and typical rates of loss are summarized below:

<u>Solvent</u>	<u>Vapor Loss From an Idling Degreaser</u>
Perchloroethylene	1.43 kilograms/m ² /hour
Methylene Chloride	1.27
1,1,1-Trichloroethane	0.69
Trichloroethylene	0.98

This study identified no users who have attempted to quantify individual components of solvent loss. Specific users are primarily concerned about total solvent consumption (i.e. the cost to operate the degreaser) and the concentration of vapor in working areas (i.e. compliance with occupational regulations). Generalized data for vapor losses were not available from solvent suppliers or equipment manufacturers. Discussions with operators and suppliers suggest that user inattention to good operating practices is a major factor contributing to excessive vapor losses from degreasers. For example, failure to cover idling degreasers and boilover of vapor through open tank surfaces appear to be relatively common occurrences. Another concern is the inattentive use of spray lances.

3.2.2.6 Degreasing Solvents. Trichloroethylene, 1,1,1-trichloroethane, perchloroethylene and methylene chloride are all commonly used as degreaser solvents. The selection of one of these solvents for a specific degreasing application depends on three general factors:

- o the cleaning ability of the solvent for the specific contaminants to be removed from the work pieces,
- o the compatibility of the solvent with the work and with the degreaser itself (with respect to corrosion, etching, pitting, oxidizing, staining or dulling),
- o the net cost of operation with the solvent.

An excellent detailed discussion of the numerous specific considerations which influence solvent selection is available in technical literature produced by the solvent suppliers (Dow, 1981). In most industrial degreasing applications, two or more solvents fulfill the technical requirements and the selection is made on the basis of economic considerations. In many cases the choice of solvent (and/or supplier) may change as costs fluctuate.

3.2.2.7 Specific Degreasing Applications in British Columbia. The use of solvent degreasing by industry is characterized by its diversity. It is estimated that there are at least 60 package or custom-designed vapor degreasing units in British Columbia, chiefly located in the Lower Mainland (L. Setterfield, pers. comm., 1982). These units range in size from small tank units used in the manufacturing of precision electronic components (with a 0.3 square meter tank surface, holding a few liters of solvent), to large tank units used to clean dismantled locomotive engines (with a 10 square meter tank surface, holding thousands of liters of solvent). The units range in complexity from simple open-top tanks to fully-automated, continuous conveyORIZED units with automatic spray systems.

Principal users of vapor degreasers in British Columbia include:

- o all types of shops engaged in the fabrication and manufacturer of metal products,
- o electroplating shops,
- o large vehicle or equipment repair shops or terminals, including rail, air and truck repair,
- o manufacturers of electronic equipment.

Table 3.2.3 summarizes the quantities of solvent used in various vapor degreasing operations carried out in British Columbia. It is estimated that vapor degreasing accounts for 307.8 tonnes of solvents in 1981, representing 13.3% of all chlorinated solvents used in British Columbia.

3.2.2.8 Problem Areas. Problems associated with environmental releases of chlorinated solvents from degreasing operations can be categorized as follows:

TABLE 3.2.3 ESTIMATED SOLVENT USE FOR VAPOR DEGREASING IN BRITISH COLUMBIA

Solvent	Application	Numbers of Users	Quantity of Solvent Used Tonnes/Year (1981)	% of Total Specified Solvent Use Consumed in Vapor Degreasing
Perchloroethylene	Mfg. Electronic Equipment	(1)	9.0	0.7 (Incl. Dry Cleaning)
	Vehicle Maintenance	(2)	0.6	38.6 (Excl. Dry Cleaning)
Methylene Chloride	Mfg. Metal Products	(8)	12.0	
	Electroplating Preparation	(2)	8.0	5.6
	Mfg. Electronic Components	(1)	1.0	
1,1,1-Trichloroethane	Mfg. Metal Products	(4)	5.1	10.7
	Vehicle/Equipment Repair	(7)	27.1	
Trichloroethylene	Mfg. Metal Products	(6)	100.0	
	Mfg. Electronic Components	(1)	13.0	
	Equipment Repair Shops	(4)	4.1	88.5
	Transport Vehicle Repair Shops (Rail, Air, Truck)	(3)	55.5	
	Electroplating Preparation	(1)	13.0	
Perc/1,1,1-Tri 50/50 Mixture	Vehicle Repair	(2)	31.0	
	Mfg. Metal Products	(2)	15.4	100.0
	Equipment Repair Shops	(1)	13.0	
All Solvents			307.8 tonnes/year	13.3% Incl. Dry Cleaning 31.4% Excl. Dry Cleaning

- o evaporative releases in the work environment, and
- o releases of residual liquid solvent in solvent/soil mixtures, still bottoms or sludges.

3.2.2.8.1 Workplace Exposures. Evaporative releases to the work environment originate in one or more of the ways described in the previous sections.

Numerous occupational surveys of degreaser operations have been undertaken by the U.S. EPA (1981), Fuller (1976), Lewis (1980) and Agatha Corp. (1976). The studies confirmed the need for proper design, operation and maintenance of vapor degreasers. Use of covers, for example, showed emission reductions by as much as 50%, and refrigerated cooling coils reduced emissions from 50 to 80% (U.S. EPA, 1981). Occasionally worker complaints were noted even though air concentrations were below NIOSH recommended levels (Lewis, 1980). Data from these studies and from on-site monitoring by specific users in British Columbia demonstrate that solvent levels in worker areas can be maintained at safe levels (well below permissible vapor levels specified by workplace regulations) when degreasers are carefully operated.

Monitoring undertaken by the B.C. Worker's Compensation Board during facility inspections shows that solvent vapor levels in worker areas can range as high as 10 times permissible levels under adverse circumstances. Such occurrences are usually associated with one or more of the following factors:

- o failure to follow normal good operating practice,
- o poor degreaser equipment design,
- o inadequate ventilation in working areas.

Those familiar with the industry suggest that failure to follow normal good operating practice is probably the most significant cause of worker exposure to high solvent vapor levels. One supplier estimated that less than 30 percent of degreaser users "follow the book" in terms of degreaser equipment maintenance procedures.

Vapor emissions to the workplace and other evaporative losses of solvent are ultimately discharged to the atmosphere. There is no evidence that emissions of degreasing solvents to the atmosphere result in significant adverse impact on the British Columbia environment.

3.2.2.8.2 Waste Disposal. Degreaser sludges, still bottoms and sludges generated from distillation of dirty solvent constitute the only significant source of potential liquid solvent release to the environment from degreasing operations. Accurate data on quantity and composition of degreaser waste sludges could not be obtained from individual B.C. users. The literature suggests that vapor degreasing sludges contain 30 to 50 percent residual solvent, depending on the efficiency of the distillation process which is used (Great Britain Dept. of Environment, 1976). Undistilled dirty solvent could contain more than 70 percent solvent.

Discussions with waste transporters/disposers suggest that many degreasing sludges generated in British Columbia are not disposed in facilities appropriate for chlorinated hydrocarbon solvents. One member of industry expressed the opinion that most generators are unwilling to pay the cost for disposal of these sludges in a secure landfill located out of province. There is no accurate quantitative information describing the disposition of solvent sludges in British Columbia. However, discussions with users indicate that it is common practice for users to evaporate sludges by prolonged storage on-site in open drums. The sludge is then removed with other conventional solid waste to a municipal landfill.

There are currently no disposal facilities in B.C. which have Waste Management Branch approval for accepting chlorinated hydrocarbons. One in-province waste disposal firm reportedly collects degreaser wastes, mixes them with fuel oil and incinerates them to recover the energy content. This allegation could not be confirmed and the company in question refused to grant permission for a site visit.

At least two B.C.-based firms accept degreaser sludges for transport to EPA approved secure landfills located in the U.S. These transporters are of the opinion that the transported waste represents a small fraction of chlorinated solvent-containing wastes generated in the province.

No solvent reclaim facilities are currently available in British Columbia. Two solvent suppliers (one B.C.-based, one U.S.-based) provide reclaim services for clients. Dirty solvent is transported to reclaim facilities in the U.S. in both cases. The client is issued a credit for the value of the recovered solvent. Similar services are being considered by other suppliers. Reclaim facilities are not considered to be economically self-supporting at the current level of solvent used in B.C. Distributors offering such services generally consider reclaim as a service which will attract solvent sales from client users with a difficult or costly disposal problem.

3.2.3 Cold Solvent Cleaning

3.2.3.1 Process Description. Cold cleaning of metal work pieces is carried out by manually dipping, spraying or brushing the dirty metal parts with cleaning solvent contained in a simple metal basin or tank. Cold cleaning is often utilized by shops where the demand for cleaning is intermittent or non-demanding in terms of residual oil/soil on the work piece. Cold cleaning to remove oils, waxes, greases; tars or fluxes is a common operation in the fabrication of metal products.

3.2.3.2 Points of Solvent Loss. Solvent losses are associated with inadequate use practices and disposal of spent solvents and solid wastes which contain solvents. Because of the nature of cold cleaning application (small volume, numerous untrained users), control of use practices and disposal of dirty solvents and sludge is probably minimal compared to practices associated with the other solvent uses.

3.2.3.3 Quantities of Solvent Loss. Material balances for cold solvent cleaning have not been determined. It is assumed that losses are entirely confined to air emissions and solid wastes.

3.2.3.4 Specific Applications in British Columbia. Table 3.2.4 summarizes specific cold cleaning applications in British Columbia. General cleaning of metal parts or equipment in 67 different shops accounts for 67 percent of all cold cleaning solvent use. This primary application is characterized by numerous users of relatively small volumes of solvent. Cold inhibitor formula 1,1,1-trichloroethane is the chlorinated solvent used almost exclusively for cold degreasing in shops. Non-chlorinated solvents (such as varsol) are also widely used for cold degreasing.

Ten firms engaged in the manufacturing of metal doors and windows utilize 37.5 tonnes/year (1981) of methylene chloride for cleanup of the applicators for the mastic sealant used to mount glass in the metal frames. This constitutes the second largest application of cold cleaning in terms of quantity of solvent used.

Other cold solvent cleaning applications include:

- o the cleanup of foam heads used in the manufacture of foamed plastic products,
- o degreasing and cleaning of compressed gas cylinder heads prior to charging the cylinders with gas,
- o the cleaning of motion picture film by professional laboratories, and
- o the cleanup of printing plates in print shops.

3.2.3.5 Problem Areas. The primary concerns are control of air emissions in the workplace and disposal of sludges. Water vapor barriers are frequently floated on solvent surfaces in cold degreasing tanks in order to reduce evaporative losses. This provides some measure of control for releases of solvent to the workplace. However, worker exposure to solvent during cleaning operations is potentially high because of the manual activity required for many cold cleaning operations. The problems associated with sludge disposal are similar to those described in Section 3.2.2.8.2 (disposal of vapor degreasing sludges).

TABLE 3.2.4

ESTIMATED SOLVENT USE FOR COLD DEGREASING IN BRITISH COLUMBIA

Solvent	Application	Numbers of Users	Quantity of Solvent Used Tonnes/Year (1981)	% of Total Specified Solvent Use Measured in Cold Degreasing or Cleaning Operations
Perchloroethylene	Print Shop Cleanup	(1)	3.0	0.2 (Incl. dry cleaning)
				12.1 (Excl. dry cleaning)
Methylene Chloride	Mfg. Metal Window, Door Frames Sealant Cleanup	(10)	37.5	13.9
	Plastic Mfg. Foam Head Cleanup	(4)	14.6	
1,1,1-Trichloroethane	Shop Cleaning Equipment Repair	(44)	104.7	50.5
	Vehicle Repair	(5)	13.1	
	Metal Fabrication	(18)	20.0	
	Gas Cylinder Head Cleaning	(3)	4.9	
	Other: Labs	(2)	8.7	
	Film Cleaning	(2)		
Plastic Cleanup	(1)			
Printing Cleanup	(1)			
Trichloroethylene	--		0	0
Perc/1,1,1-Tri 50/50 Mixture	--		0	0
All Solvents		91	206.5	8.9% Incl. Dry Cleaning 21.6% Excl. Dry Cleaning

3.2.4 Commercial Furniture Refinishers, Paintstrippers. Commercial furniture refinishers make up one of the largest single categories of industrial users of methylene chloride. Two large operations account for 35 tonnes/year (1981) or 9.3 percent of all methylene chloride purchases in the province. It is estimated that about two-thirds of this solvent is resold to numerous other refinishing shops. Additional quantities of formulated strippers are imported from eastern Canada and the U.S. for use by smaller commercial refinishing operations although accurate information about the quantity of these purchases could not be obtained.

Use practices of commercial refinishers vary considerably. Small operations may utilize a brush-on formulation which contains methylene chloride, often in a gel-like base to retard solvent evaporation. The softened finish is then removed by scraping and discarded with conventional refuse.

Large commercial operations often remove paint or varnish by immersing the work piece in methylene chloride liquid contained in a large tank. The finish is then removed manually with scrapers or stiff brushes. The sludge generally accumulates in the work tank and is periodically transferred to drums for disposal. Much of this sludge is disposed in a conventional municipal landfill or stored indefinitely on-site.

Commercial refinishers who utilize tank baths often float a thin layer of non-volatile liquid (paraffin or water) on the methylene chloride surface to retard evaporation of the stripping solvent. Paraffin has been used successfully, although the safe liquifaction of paraffin poses practical problems (for example, heating contributes to excessive evaporation of the methylene chloride). Water layers are effective in controlling evaporation, but may cause waterlines on the stripped furniture and lead to unacceptable quality in the finished work.

An enclosed and automated methylene chloride stripping process is used by one operation in British Columbia. The closed system is refrigerated to minimize solvent evaporation and the process utilizes spray jets to effect removal of the softened finish. Although the system provides improved control

of solvent vapor, the approach is resisted by other large commercial finishers because it is less efficient (i.e. slower) at stripping furniture and requires a high capital investment (about 15 times the cost of the manual tank system).

The principal concerns about solvent use by refinishers are:

- o excessive exposure of workers to methylene chloride, and
- o disposal of paint and varnish sludges containing residual methylene chloride.

3.2.5 Miscellaneous Applications. Several miscellaneous applications for chlorinated hydrocarbon solvents were identified in British Columbia. The most significant application in terms of quantity of solvent consumed consists of the use of methylene chloride as a surface treating agent in the refinishing of ABS plastic items. A new thin surface layer of ABS plastic is sprayed on the old item. This is then bonded to the underlying original surface by exposure to methylene chloride vapor. The treatment is carried out in a conventional open-top vapor degreaser. The process is employed by a single firm and consumes 30 tonnes/year or 8 percent of all methylene chloride used in British Columbia. The process produces a plastic-containing solvent mixture which is periodically concentrated in the degreasing tank, transferred to drums and removed by an in-province waste hauler. The disposition of the sludge was not known and the discharge of the waste was not regulated by an existing permit.

A second application consists of the use of a solvent-based woodfiller by a single plywood manufacturing operation. This use represents 25 tonnes per year or 11 percent of all trichloroethylene consumed in B.C. (1981). Virtually no solvent containing waste is produced by this application.

Relatively small quantities (0.7 tonnes/year in total) of methylene chloride and 1,1,1-trichloroethane are used by analytical laboratories, chiefly in materials testing of asphalt.

Approximately 2 tonnes/year of perchloroethylene are used by a single firm which utilizes a new process for photoengraving on a polymer base. The solvent is recovered and redistilled on-site. A waste sludge from the process

reportedly contains 16 percent residual perchloroethylene and permission to dispose of the sludge in sanitary landfill was denied by the municipality. Approximately 12 drums/year (2 tonnes/year) of this sludge is transported to the U.S. for disposal in an EPA-approved secure landfill. The residual solvent in the sludge represents 15 percent of the total solvent use.

3.2.6 Product Formulation.

3.2.6.1 Specific Applications. The production of formulated products is carried out by twenty firms and consumes 15.7 percent of all chlorinated solvent used in British Columbia (1981). The distribution of solvent types among the major categories of formulated products is shown in Table 3.2.5. Total chlorinated solvent use is divided approximately equally among three primary classes of formulated products produced in British Columbia:

- o degreasing solvents and formulated cleaning compounds for industrial use,
- o industrial adhesives and glues, and
- o formulated paint strippers for the domestic retail market.

In addition to the above-listed applications, small quantities of perchloroethylene are repackaged for distribution to analytical laboratories and 3.0 tonnes/year of methylene chloride is used in the manufacture of printing inks. No chlorinated solvents are used in B.C. in the manufacture of paint products (other than strippers as noted above).

Degreasing solvents and cleaning compounds are produced by eight firms. These products utilize all the subject solvents although methylene chloride is the primary active ingredient in terms of quantity of solvent use. Industrial adhesives incorporate methylene chloride or 1,1,1-trichloroethane as a volatile carrier of the adhesive ingredient. Adhesives are typically 60 to 80 percent solvent. Industrial adhesives are utilized in a wide variety of applications including the fabrication of wood, paper and cardboard products, label fixation, and use in the construction industry. Formulated paint strippers are manufactured by at least 5 firms in British Columbia. This product is typically

TABLE 3.2.5 ESTIMATED SOLVENT USE FOR FORMULATED PRODUCTS IN BRITISH COLUMBIA

PRODUCTS	SOLVENT USE (tonnes/year)				All Solvents
	Perchloroethylene	Methylene Chloride	1,1,1-Trichloroethane	Trichloroethylene	
Degreasers, Cleaners	12	68	15	0.5	95.5
Adhesives		51.4	100		151.4
Analytical	0.3				0.3
Inks		3			3
Paint Strippers		114			114
All Products	12.3	236.4	115	0.5	364.2

15.2% of all solvent use in B.C.

50 percent methylene chloride, often contained in a gel base to facilitate use in a household setting. Nearly all of the formulated strippers produced in B.C. are directed at the domestic consumer market.

3.2.6.2 Imports and Exports. Product formulators are highly protective of market information and data was not obtained to accurately quantify imports and exports of these products from B.C. Most producers and suppliers expressed the opinion that there is only minor exchange of formulated products between British Columbia and the United States. However, there is a significant exchange of formulated products between producers and users in British Columbia and other Canadian Provinces. Large B.C. formulators generally service a market area including two or more of the provinces of Western Canada. Furthermore, there is apparently considerable importation of formulated products from Eastern Canada to B.C. users.

One producer estimated that about 20 percent of the B.C. market for industrial adhesives is supplied by in-province production, the balance being supplied by firms in Eastern Canada or the United States. The same formulator indicated that 55 percent of his firm's product is marketed in Alberta. A similar pattern emerged in discussions with formulators of paint strippers for the domestic retail market. Major producers in B.C. serve a market in Western Canada and share the B.C. market with Eastern producers.

3.2.6.3 Problem Areas. In general, few problems associated with solvent release were identified in operations of product formulators. There is high motivation for good control of solvent in these facilities, since solvent loss is directly related to dollar loss in terms of reduced production. Formulators typically claim to produce no waste. Production operations consist primarily of mixing and filling and these are generally carried out in closed systems or isolated areas. Tank rinses or reject products are normally reused in subsequent production. Large operations receive and store solvent in bulk tankage and there is a minimal direct worker exposure to solvent in well-operated facilities. Isolation of solvent working areas, overall space ventilation and individual ventilation pickups at product container filling stations are used to control solvent vapor levels.

3.3 Summary of Use Practices and Environmental Releases

Tables 3.3.1 to 3.3.5 summarize chlorinated solvent use practices for the major user categories in British Columbia. The tables show the type and magnitude of process wastes, indicate the disposal and reclamation options used by industry, and comment on the nature and extent of workplace exposure to solvent liquid and vapor.

The tables are intended to provide an overall picture of solvent use practices in B.C. industry to indicate the range of practices which were encountered in site visits and personal interviews undertaken during this study. As indicated in previous sections, specific quantitative information about air emissions and waste discharges were generally not available from individual solvent users. As a consequence, the quantitative information describing process wastes and releases to the environment were largely derived from the application of judgement to information from numerous sources including discussions with knowledgeable industry personnel and "guesstimates" provided by solvent users.

The information in Tables 3.3.1 to 3.3.5 can be generalized with reasonable accuracy to provide an overview of solvent use by all user industries in B.C. General conclusions include the following:

- o Evaporative losses constitute the major component of solvent consumption. As much as 90% of consumed solvent is lost to air in the routine operations of solvent use.
- o Readily available state-of-the-art equipment generally reduces total solvent consumption substantially when it is employed by users. In many cases modern equipment can reduce total solvent consumption (by a specific user) by 50 to 90%. The chief impediment to installing state-of-the-art equipment is cost, although rapidly escalating solvent costs are softening resistance.
- o Use of poor operating practices contributes significantly to solvent consumption. Technical expertise and information to correct poor practice is readily available at no cost from solvent manufacturers and suppliers. Many users have not used this resource effectively.

TABLE 3.3.1 SUMMARY OF SOLVENT USE PRACTICES AND ENVIRONMENTAL RELEASES
PRODUCT FORMULATION (See Section 3.2.6)

PROCESS	Product formulation of: o degreasers, cleaners, industrial adhesives o paint strippers for domestic use				
PROCESS EQUIPMENT DESCRIPTION	o mixing and blending tanks o container filling stations				
NO. OF USERS	20 (formulators)				

SOLVENTS USED*:	PERC	MC	1,1,1-TRI	TCE	Total
ANNUAL CONSUMPTION (Tonnes/year)	12.3	236.4	115	0.5	364.2

RELEASES TO THE ENVIRONMENT	To Air:	on-site evaporative loss-less than 5% of consumption evaporative losses from formulated products occur at the user site. For most products, virtually all solvent evaporates during use.			
	To Water:	negligible			
	To Land:	negligible			

PROCESS WASTES	Source:	none reported			
	Quantity:	-			
WASTE DISPOSAL		Not required			
RECLAMATION		Rinses or reject product batches are recycled to new product			

WORKER EXPOSURE	To Liquid:	low if good practices are followed			
	To Vapor:	low if good practices are followed and proper ventilation is provided			
WORKPLACE EXPOSURE LEVELS		Generally within permissible levels			

*PERC=perchloroethylene
MC=methylene chloride
1,1,1-TRI=1,1,1-trichloroethane
TCE=trichloroethylene

TABLE 3.3.2 SUMMARY OF SOLVENT USE PRACTICES AND ENVIRONMENTAL RELEASES
COMMERCIAL FURNITURE STRIPPING (see Section 3.2.4)

PROCESS	Commercial Furniture Stripping/Refinishing
PROCESS EQUIPMENT DESCRIPTION	o dip tank with manual scrape/scrub o 1 user operates a refrigerated, closed system
NO OF USERS	20 +

SOLVENT USED:	MC
ANNUAL CONSUMPTION (Tonnes/year)	35 + imported formulations (est. 20+)

RELEASES TO THE ENVIRONMENT	To Air: on-site evaporative loss-90+ percent of consumption
	To Water: negligible
	To Land: sludges, residual solvent estimated at 10% of solvent consumption

PROCESS WASTES	Source: tank sludges containing removed paint, finishes, residual solvent
	Quantity: unknown, sludge volume could be 10-90% volume of solvent consumption

WASTE DISPOSAL	o to sanitary landfill after evaporation in open drums o to out-of-province secure landfills
RECLAMATION	Not applicable with tank systems

WORKER EXPOSURE	To Liquid: potentially high if proper precautions are not observed
	To Vapor: potentially high if proper precautions are not observed

WORKPLACE EXPOSURE LEVELS	.05 to 10 times the permissible level
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TABLE 3.3.3 SUMMARY OF SOLVENT USE PRACTICES AND ENVIRONMENTAL RELEASES
COLD SOLVENT DEGREASING (See Section 3.2.3)

PROCESS	Cold Solvent Degreasing			
PROCESS EQUIPMENT DESCRIPTION	simple bath or tank, typically 10's of liters capacity			
NO OF USERS	91			
SOLVENT USED:	PERC	MC	1,1,1-TRI	Total
ANNUAL CONSUMPTION (Tonnes/year)	3.0	52.1	151.4	206.5
RELEASES TO THE ENVIRONMENT	To Air:	on-site evaporative loss 90+ percent of consumption, frequently slowed by water layer barrier		
	To Water:	negligible		
	To Land:	sludge,-residual solvent less than 10% of consumption		
PROCESS WASTES	Source:	sump sludges		
	Quantity:	highly variable		
WASTE DISPOSAL	o to municipal landfill after solvent residue is evaporated to atmosphere on-site o returned to solvent supplier (uncommon)			
RECLAMATION	Uncommon			
WORKER EXPOSURE	To Liquid:	potentially high if good practice is not followed		
	To Vapor:	potentially high if good practice is not followed		
WORKPLACE EXPOSURE LEVELS	.05 to 10 times permissible levels, depending on practice			

TABLE 3.3.4 SUMMARY OF SOLVENT USE PRACTICES AND ENVIRONMENTAL RELEASES
VAPOR DEGREASING (See Section 3.2.2)

PROCESS	Vapor Degreasing						
PROCESS EQUIPMENT DESCRIPTION	<ul style="list-style-type: none"> o open tank bath degreasers from less than 5 to 1000's of liters sump capacity o enclosed continuous degreasers more than 300 liters sump capacity; most large units have external stills 						
NO OF USERS	45+ (60+ units)						
SOLVENT USED:	PERC	MC	1,1,1-TRI	TCE	PERC/ 1,1,1-TRI	Total	
ANNUAL CONSUMPTION (Tonnes/year)	9.6	21.0	32.2	185.6	59.4	307.8	
RELEASES TO THE ENVIRONMENT	<p>To Air: on-site evaporative loss 50% of consumption (no on-site still) -90% of consumption (on-site still)</p> <p>To Water: negligible</p> <p>To Land: still bottoms (generally after on-site evaporation) residual solvent 10 to 15% of total consumption</p>						
PROCESS WASTES	<p>Source: sump residues (infrequently) still bottoms sludges (daily or weekly)</p> <p>Quantity: still bottoms sludge volume: 20-30% of fresh solvent makeup volume</p>						
WASTE DISPOSAL	<ul style="list-style-type: none"> o to municipal landfill after solvent is reduced by evaporation (open top drums) o to out-of-province secure landfills o returned to supplier for disposal or reclaim 						
RECLAMATION	<ul style="list-style-type: none"> o on-site stills common with large degreasers o out-of-province reclaimers are used by several firms 						

cont'd . . .

TABLE 3.3.4 cont'd (VAPOR DEGREASING)

WORKER EXPOSURE	To Liquid: minimal if routine precautions are observed
	To Vapor: low to high, depending on observance of accepted good operating practice
WORKPLACE EXPOSURE LEVELS	.05 to 10 times permissible levels, depending on practice

TABLE 3.3.5 SUMMARY OF SOLVENT USE PRACTICES AND ENVIRONMENTAL RELEASES
DRY CLEANING (See Section 3.2.1)

PROCESS	Dry Cleaning
PROCESS EQUIPMENT DESCRIPTION	<ul style="list-style-type: none">o residential shops-predominantly hot machines, absorbant cartridge filters, no stillso commercial plants-transfer machines, diatomaceous earth filters, double stills
NO OF USERS	<ul style="list-style-type: none">o 800 residential shops (throughout B.C.)o 3 large commercial/industrial shops (Lower Mainland)

SOLVENT USED	Perchloroethylene (exclusively)
ANNUAL CONSUMPTION (Tonnes/year)	1,335

RELEASES TO THE ENVIRONMENT	<p>To Air: evaporative loss 80% of consumption -greater than 40% vented to atmosphere -less than 40% to workplace</p> <p>To Water: negligible</p> <p>To Land: filter media (containing residual solvent) and still bottoms (where applicable) -residual solvent 5 to 20% of consumption</p>
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PROCESS WASTES	<p>Source: filter media (cartridge or sludge) still bottoms (sludge)</p> <p>Quantity: residual solvent: less than 20% of total solvent consumption (probably substantially less with improved recovery techniques)</p>
WASTE DISPOSAL	<p>Cartridges-to sanitary landfill after draining to recover residual solvent (sometimes heated)</p> <p>Still bottoms-to sanitary landfill</p>
RECLAMATION	<ul style="list-style-type: none">o state-of-the-art systems are closed systems with efficient vapor recoveryo typical equipment uses various types of vapor recovery including condensers and carbon absorberso on-site stills or absorptive filters used to reclaim liquid solvents

TABLE 3.3.5 (cont'd) (DRY CLEANING)

WORKER EXPOSURE

To Liquid: Minimal exposure; solvent generally delivered in bulk (directly to the system tank) and totally contained during process operation. Only routine exposure to liquid solvent is during filter change.

To Vapor: Normally low; potentially high (poor practices). Well within workplace limits for well-maintained equipment and good operating practice. Can exceed workplace limits in the presence of leaky equipment, poor ventilation and/or poor practice.

WORKPLACE EXPOSURE LEVELS

0.001 to 10 times permissible levels (based on U.S. case studies. No B.C. data are available)

- o Solvent processes generally do not produce liquid wastes.
- o The primary solid waste from solvent processes is sludge containing various oils, waxes and cleaning soils. Residual solvent in these sludges is of the order of 10-20% of the total weight of the sludge.
- o Disposal of sludge is the principal dilemma facing many solvent users. Regulatory agencies consider chlorinated hydrocarbon containing sludges unsuitable for disposal in conventional landfills and often prohibit such disposal. However, acceptable disposal facilities are not available in B.C. and transport out-of-province is considered prohibitively expensive by most users (at a cost of about \$80 per 45 Imperial Gallon drum). Many users circumvent this problem by evaporating residual solvent from sludges to the atmosphere and/or by disposing of the sludge as a conventional waste to sanitary landfill. In many cases, regulatory agencies do not appear to be aware that this practice is occurring.
- o On-site reclamation and recovery is increasing in extent of application and effectiveness. It is likely that this trend will continue in view of the high price of chlorinated solvents.
- o Off-site reclamation at U.S. sites is available through distributors, often as a service enticement to secure solvent sales. There are currently no B.C. reclamation facilities and the volumes of chlorinated solvent used in B.C. is probably insufficient to provide economic viability for such a facility.

3.4 Risk Assessment Related to Uses of Chlorinated Solvents in British Columbia

This section reviews efforts in British Columbia to minimize environmental releases of the chlorinated solvents and to minimize risks associated with the use of the solvents. Risk assessment associated with the use of any chemical requires an integration of many factors including:

- o toxicity of the chemical,
- o time of exposure to the chemical,
- o exposure concentration,
- o method of exposure (i.e. skin contact, swallowing, breathing),
- o controls to minimize probability of exposure.

Therefore, a very toxic chemical used with very stringent controls may be less of a hazard than a moderately toxic chemical used without much precaution.

3.4.1 Present Controls on Uses and Releases of Chlorinated Solvents in British Columbia. There are several sources of control or incentives for control of uses and/or releases of chlorinated solvents in British Columbia. It is the view of the investigators that the most effective controls in British Columbia are those of the manufacturers and suppliers of the solvents. The users themselves have a financial incentive to recycle as much solvent as possible for reuse, due to the dramatic increase in cost of solvents during the past several years. The controls resulting from industrial hygiene requirements of the Workers' Compensation Board are moderately effective for minimizing releases to the environment. The controls (where applicable) of municipal, provincial and federal pollution control departments or agencies have been marginally effective in the past.

3.4.1.1 Controls by Manufacturers and Suppliers of Solvents. The industry associated with the manufacture and supply of chlorinated solvents has taken a strong self-regulating approach to the control of use and release of the solvents. There is a concern by the industry that misuse of a product by any one user may appreciably affect the entire market for the product and/or result in government regulations which may be overly stringent in the view of industry.

The controls of manufacturers and suppliers take the form of:

- o Educational Information and Guidelines in Solvent Handling - Attempts are made to provide every user of bulk solvents with material safety data sheets which contain: physical data; fire and explosion hazard data; reactivity data; spill, leak, and disposal procedures; health hazard data; first aid procedures; special

handling information; and, special precautions. Appendix II contains examples of data handling sheets for the four solvents of particular interest in this study.

Dow Chemical, for example, publishes detailed technical brochures which describe solvent characteristics, safe handling practices, and considerations for degreaser solvent selection. The company also provides position papers which describe solvent use practices and present background information on health and environmental concerns.

- o Guidelines for Equipment Design, Selection and Operation-Both Dow Chemical and C-I-L provide guidelines for the design and operation of degreasers. The guidelines provided by Dow Chemical are extensive and written in a format similar to a code of good practice. C-I-L, through its affiliate Canadian Hanson, designs and builds degreasers which contain state-of-the-art control measures to minimize releases of degreasing solvents. Operating guidelines are provided to all users of this equipment.
- o On-site Inspections-The frequency of on-site inspections by representatives of suppliers and manufacturers is highly variable -from nonexistent to frequent. The inspection may vary from a cursory review of usage practices to a detailed assessment of, for example, design features or monitoring of atmospheric emissions. Most solvent distributors will readily provide competent technical expertise upon request of solvent users who experience problems.
- o Provision of Immediate Information-Most solvent manufacturers and suppliers provide users with emergency phone numbers. This enables immediate access to information about any aspect of solvent use or handling if the user encounters problems.
- o Provision of Recycling Facilities-There are currently no recycling facilities in British Columbia, however, one of the American suppliers of trichloroethylene to British Columbia does provide

recycling services and credits its major B.C. customer for quantities of solvent returned for recycling. One major Vancouver supplier of solvents to the B.C. market is currently conducting a feasibility study for a recycling facility in the Lower Mainland. Another B.C. distributor claims to provide "total customer service" to clients who purchase large quantities of chlorinated solvents. This service includes provision of waste disposal of spent solvents and contaminated sludges via facilities in the U.S.

3.4.1.2 Controls of Trade Associations. The majority of dry cleaners in British Columbia are members of the B.C. Fabricare Institute, which is in turn affiliated with the International Fabricare Institute. As well as receiving periodic trade news, members are provided with technical bulletins which describe equipment and process improvements and outline recommended procedures for handling and control of chemicals used by the dry cleaning industry. The International Fabricare Institute is one of the six trade associations which comprise the Laundry Cleaning Council. The Council, with an apparently larger resource base, has prepared, in layman's terms, information on the safe handling of perchloroethylene dry cleaning solvent.

Trade associations of other users were not identified during this study.

3.4.1.3 Controls by Solvent Users. Two main factors are responsible for the increasing level of controls by users of solvents:

- o concern for worker and personal (i.e. owner-operator) health,
- o concern about the escalating costs of solvents.

Although there has always been concern about health issues, the added incentive of increasing solvent cost has motivated some of the more intensive measures for controlling solvent emissions to enable recycling. For example, many dry cleaning operators faced with perchloroethylene solvent cost increases from \$3.00 per gallon in 1975 to \$8.25 per gallon in 1982, have been installing more sophisticated process equipment and vapor collection systems to minimize solvent losses. As described in Section 3.2.1.1.6, such equipment includes:

- o single machine ("dry-to-dry") units versus two machine ("transfer") systems,
- o closed loop refrigerant coolers to provide maximal solvent removal from exhaust air,
- o carbon "sniffers" to capture solvent vapors lost to air in exhaust vents.

Dry cleaning facilities with state-of-the-art equipment are characterized by the absence of perchloroethylene odors throughout the workplace. The effectiveness of the equipment is also reflected in the decreased quantities of perchloroethylene used per quantity of clothing cleaned. Decreases in solvent usage by as much as 70% were reported by operators visited during this study. Such decreases in usage factors are accompanied by much lower exposure levels to workers and in a holistic sense indicate reduced releases to the environment via air and water.

One dry cleaning owner-operator expressed the view that plants which do not modernize their equipment in the near future will not remain competitive if solvent prices keep increasing. However, the high costs and associated duties and taxation of new process equipment may make it economically feasible for plants with older equipment and higher emissions to keep functioning for the time being.

Other examples of improvements in process equipment and vapor collection systems which are generally coming into use in North America include:

- o for metal cleaning processes: the use of local ventilation systems connected directly into regenerative vapor recovery units,
- o for coating, adhesive and aerosol formulation: the use of recovery units inherent to the process streams (e.g. integral part of central exhausting in adhesive manufacture).

During the field surveys for this study, it appeared that a general transition was occurring whereby the industry on its own initiative was taking steps to minimize solvent losses to the environment. This transition is being retarded by economic and technical factors which will be described in Sections 3.4.3 and 3.4.4.

Three other types of control by users were observed during site visits undertaken in this study:

- o one plant encourages complete annual medical checkups of its key operators to assure that no health problems are occurring,
- o another plant hired an industrial hygiene consultant to extensively monitor concentrations of solvents throughout the plant site. One United States distributor of dry cleaning products similarly offers extensive monitoring at B.C. dry cleaning plants, if requested,
- o a degreasing operation changes key operators bi-weekly to minimize long-term exposure.

3.4.1.4 Controls by Industrial Health Regulations. Section 3.3 indicated that air emissions are the most important pathways for the releases of the subject chlorinated solvents to the British Columbia environment. The programs required under the Industrial Health and Safety Regulations of the Workers' Compensation Board of British Columbia, although designed for worker safety, are at this time the most effective controls on air emissions of chlorinated solvents to the environment. Examples of the regulations include:

- o Section 70 - Laundries and Dry Cleaning Plants. This Section prohibits dry cleaning in open vessels except as required for spotting (Reg. 70-03), and specifies storage and handling requirements for solvents (Regs. 70.07 and 70.13), and ventilation requirements (Regs. 70.13, 70.15, 70.27 and 70.29). Regulation 70.17 states that "all dry cleaning machines and equipment shall be designed, installed and operated so as to prevent the escape of solvent liquid or vapor, and to maintain workroom concentrations of solvent vapor at or below the concentrations listed in Appendix "A" (of the Industrial Health and Safety Regulations)".

- o Section 13 - Health Hazards and Work Environment Controls. This Section outlines the limitations on worker exposure to airborne contaminants (Reg 13.01) and ventilation requirements (Regs. 13.37, 13.41, 13.43, 13.45, 13.47, 13.49, 13.51, 13.55 and 13.59). The limitations refer to Appendix "A" of the regulations which states the following permissible concentration for airborne contaminant substances of interest to this study: methylene chloride - 200 ppm permissible 8 hour limit and 250 ppm permissible 15 minute limit; perchloroethylene - 100 ppm permissible 8 hour limit and 150 ppm permissible 15 minute limit; 1,1,1-trichloroethane - 1900 ppm permissible 8 hour limit and 440 ppm permissible 15 minute limit; and, trichloroethylene - 100 ppm 8 hour limit and 150 ppm 15 minute limit.

- o Section 20 - Painting and Coating. This Section outlines regulations which address: worker education, handling and use of solvents, ventilation and use of personal protective equipment (Reg. 20.01); and, operator training and use of spray equipment (Reg. 20.08).

- o Section 25 - Garage and Vehicle Repair Shops. This Section makes direct reference to degreasing tanks (Reg. 25.09) by simply indicating that airborne contaminant concentrations shall be kept at or below the concentrations listed in Appendix "A".

Inspections are frequently carried out by the Workers' Compensation Board with regard to the implementation of the regulations noted above. Visual assessments and air sampling by "Drager" tubes are components of the inspections. In cases where safety and design features are in blatant disregard for WCB regulations, shutdown of the facilities may be ordered. For example, one paint stripper in Vancouver who used methylene chloride was recently ordered to cease operation because of high risk assessment to worker safety.

The regulations of the Workers' Compensation Board of British Columbia encourage the minimization of air emissions of chlorinated solvents. However it should be noted that the regulations are written to protect the immediate environment of workers and not the total environment. It is therefore possible that minimization of localized emissions may lead to increased "total environment" emissions. For example, an effective ventilation system for a work area may require high air flows which actually increase the release rate of volatile solvents to the outside environment.

The operations of rail and airline maintenance facilities are reviewed by Transport Canada rather than the Workers' Compensation Board. The rail overhaul centre reviewed during this study was tested daily for air emissions of trichloroethylene from degreasing operations. The tests were carried out by the safety department of the centre, and the records were checked periodically by Transport Canada.

3.4.1.5 Controls by British Columbia Municipal and Provincial Governments and by the Canadian Federal Government

3.4.1.5.1 Existing Controls. Air quality and effluent quality objectives applied to British Columbia industry are pursuant to the British Columbia Pollution Control Act, 1967. However, the objectives have no specific reference to the halogenated hydrocarbon solvents of interest. For example, the British Columbia Pollution Control Objectives for "The Chemical and Petroleum Industries of British Columbia" listed objectives for 28 compounds or elements in air emissions from petrochemical, resin, and paint industries. None of the compounds listed are halogenated hydrocarbon solvents. Likewise the solvents are not included in any of the 35 categories of elements or compounds specified for restriction in wastewater effluents.

3.4.1.5.1.1 Control of Air Emissions. A review of industry during this study reveals that air emissions of the selected chlorinated solvents are directly regulated by municipalities under a mandate delegated by the B.C. Ministry of Environment. For example, air emissions in the Lower Mainland area are administered by permits of the Greater Vancouver Regional District (GVRD) under the auspices of the Pollution Control Act, 1976. The permits govern process emissions and therefore fugitive solvent emissions from the work area

(i.e. leaking dry cleaning equipment) are not regulated by the GVRD. Such a situation might be regulated if there were a nuisance problem which came to the attention of the GVRD. Therefore, regulation focuses on processes which directly emit solvents to the atmosphere (i.e. use of solvents under hooded exhaust ventilation systems), rather than general emissions from a workplace (i.e. through windows, room vents, etc.).

Permits for air emissions within the GVRD jurisdiction refer to limitations on the four selected solvents either on the basis of "hexane extractables" or on specific compounds (e.g. 100 ppm trichloroethylene). Monitoring of industry is carried out on a random basis at a frequency determined by the type of industry and nature of emissions. Frequency of monitoring may vary from several times a year to less than once a year.

3.4.1.5.1.2 Control of Emissions to Water. Wastewater discharges containing chlorinated solvents were not observed during plant inspections. Potential sources are probably limited to:

- o carbon adsorbers which require steam during desorption cycles,
- o spillage of solvent into floor drains.

Many municipalities have regulations to assure that such solvents do not enter sewerage systems. The Greater Vancouver Regional District, for example, has published regulations which govern the admission of wastes into sewers. The solvents of interest are not identified within the regulations, however their regulation could be implied under the restriction of discharge of "any water or waste which contains . . . more than 15 milligrams per litre of substances derived from petroleum sources".

It would be expected that under normal operating circumstances, chlorinated solvents would not be released to waterbodies in quantities which would contravene the Canada Fisheries Act of 1970. The low solubilities, high vapor pressures and low to moderate toxicities, would not readily qualify chlorinated solvents as "deleterious substances" unless large spills occur. One

such spill did occur in March, 1982 when 500,000 litres of 1,2 dichloroethane were released into the Thompson River after derailment of several bulk tank cars.

3.4.1.5.1.3 Control of Solid Waste Disposal. Currently solid waste disposal is controlled by municipalities within which landfills are located. Therefore, municipalities have the power to reject disposal of certain wastes at municipal landfills. In many instances the wastes are not properly identified to enable municipal review of disposal. If wastes are properly identified, rejection of permission is more probable as in the case of a user who requested permission to dispose perchloroethylene contaminated sludges at a GVRD landfill.

3.4.1.5.2 Pending Controls. The most significant pending controls which may affect use and disposal practices of chlorinated solvents in British Columbia are those proposed for "special wastes" under the Provincial Waste Management Act of 1982. Spent halogenated solvents, sludges resulting from use of these solvents, and still bottoms from recovery of the solvents have been classified as special wastes within defined limits of quantity and concentration.

Under the proposed regulations a waste generator would have to determine whether the concentration of the chlorinated solvents and the quantity of waste containing the solvent enable an exemption from classification as a special waste. The determination is based on the use of the classification curve shown in Figure 3.4.1.

If the waste qualifies as a special waste, the use of a waste transportation manifest is required using a "British Columbia Identification Number" and a "Transport of Dangerous Goods Act Identification Number". The manifest would enable the British Columbia Waste Management Branch to control transport and disposal of special wastes in the Province. Ultimately, the disposal of special wastes will be limited to approved facilities. Although there are currently no approved facilities in B.C., the Waste Management Branch is currently negotiating with industry to establish such facilities.

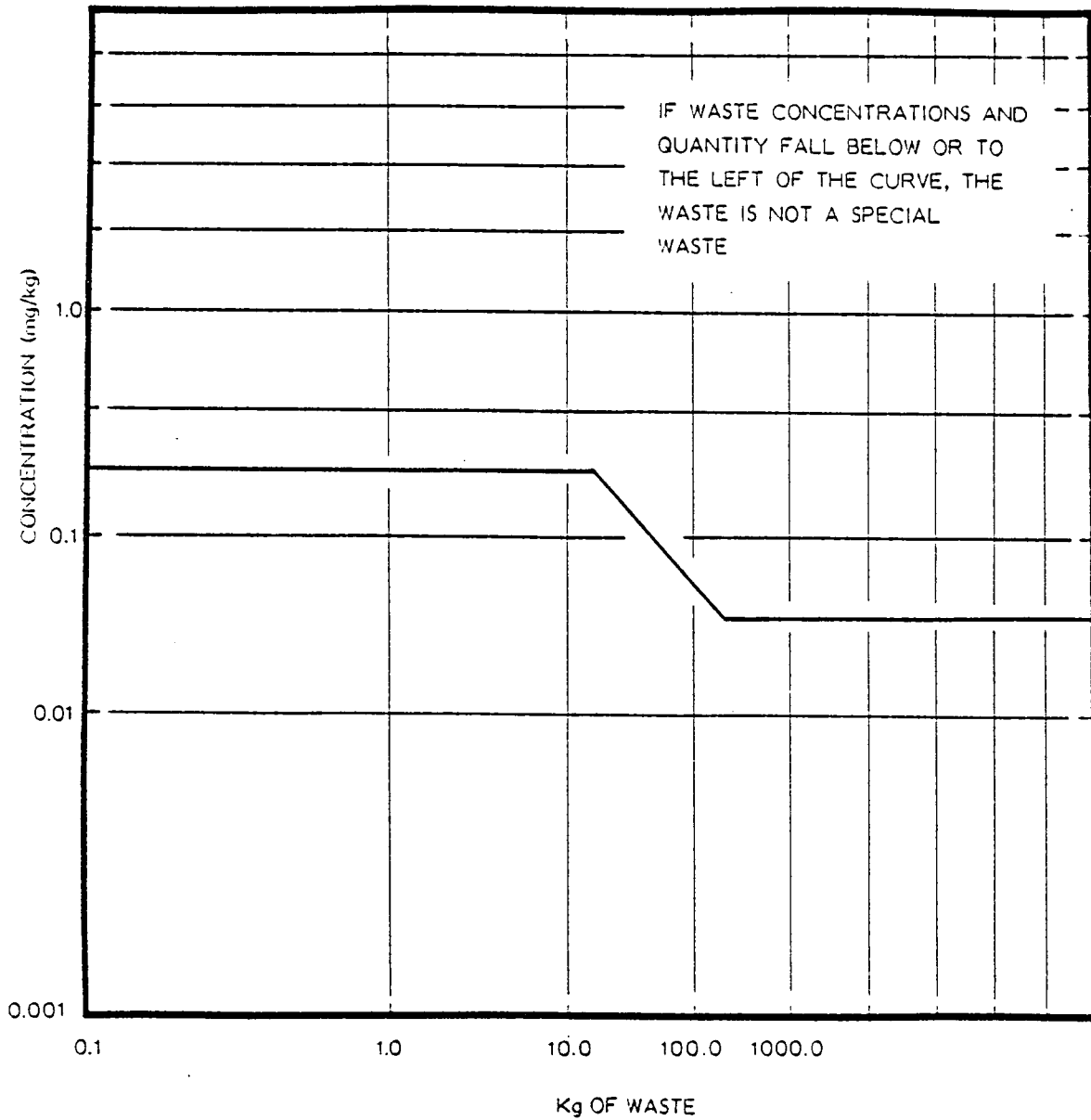


FIGURE 3.4.1. PROPOSED CURVE FOR DETERMINING CLASSIFICATION OF CHLORINATED HYDROCARBON SOLVENTS AS SPECIAL WASTES.

3.4.1.6 Controls by United States Agencies. The United States is the major source of supply for the subject chlorinated solvents used in British Columbia. There is a resulting intimate awareness by the B.C. industry of relevant American regulations and recommended controls, especially those of the National Institute for Occupational Safety and Health and the Environmental Protection Agency. Furthermore, the B.C. Workers' Compensation Board permissible levels for exposure to solvent vapors in the workplace are adopted from the Standards of the American Congress of Governmental and Industrial Hygienists.

3.4.2 Assessment of Need for Concern About Chlorinated Solvent Use in British Columbia. Section 3.3 indicated that atmospheric emissions are the most important sources of release of chlorinated solvents to the environment. Solid waste sludges are probably relatively minor sources of release of chlorinated solvents. This study found no aqueous wastes which could be considered as significant sources.

3.4.2.1 Atmospheric Emissions. Localized atmospheric emissions (such as in a workplace) are reasonably monitored and controlled by the Workers' Compensation Board of British Columbia. Point sources are monitored primarily by municipalities such as the Greater Vancouver Regional District. Some workplaces in the Province still do have high air emissions and, in most cases, appropriate remedial measures are in planning stages.

The reasons for high localized air emissions include:

- o improper maintenance of equipment,
- o inadequate design of equipment and ventilation facilities,
- o use of antiquated equipment such as degreasers with improper vapor barriers or "transfer" dry cleaning equipment, and
- o careless operator use of solvents.

It appears that the users and suppliers are conscientiously attempting to alleviate the above problems. It should be the role of Workers' Compensation Board to assure that such efforts are ongoing.

Beyond the localized workplace environment, the need for control of chlorinated solvent air emissions to the general environment is not known. There have been no known air samplings and analyses to determine ambient concentrations of chlorinated solvents in British Columbia. The evaluation of risk to the general population is therefore not possible.

The risk to the general population from exposure to ambient chlorinated solvents is probably minimal. Chlorinated solvent use in B.C. is low relative to use in more highly industrialized areas of North America. Furthermore, very low ambient concentrations have been found in other parts of the world and chlorinated solvents exhibit low toxicity relative to many other chemicals in use. For example, air monitoring of perchloroethylene in selected high population areas of the United States has shown minimal risk to populations (Evans et al., 1979). High population areas were selected because of the proportionate number of dry cleaning plants to population. New York City monitoring showed a perchloroethylene range from 0.2 to 10.6 ppb (median, 1.0 ppb). Houston, which is the major production centre for perchloroethylene, had levels from ≤ 0.1 to 4.5 ppb (median, 0.11ppb) in suburban areas near the production sites. Higher levels were always observed mid-week and during periods of atmospheric stagnation due to the absence of wind and limited vertical mixing.

The actual impact of chlorinated solvent emissions to the atmosphere continues to be a subject of active debate (e.g. Lapp, 1980). While it has been assumed that most chlorinated compounds rapidly degrade in the stratosphere (Fuller, 1976), 1,1,1-trichloroethane has been assumed to degrade much slower with lifetimes which range from 1 to 11 years. Furthermore, attention has focused on the hazards of the chlorinated compounds instead of their degradation products. Trichloroethane for example can degrade to phosgene, hydrogen chloride and acetyl chloride, all of which may be more hazardous than trichloroethane (Lapp, 1980). If it is found in the future that chlorinated hydrocarbon emissions to the atmosphere are of concern, a total global approach is the only effective means of control due to the rapid dispersal of the compounds throughout the atmosphere. A regional approach would have little effect on exposure levels, as indicated by a comparison of 2316 tonnes chlorinated solvents used in British Columbia in 1981 versus an estimated 2,000,000 tonnes used in

North America. In addition, given the ongoing trend for controls by users to minimize vapor losses, further legislative controls on regional air emissions may be relatively ineffective and unnecessary.

3.4.2.2 Solid Waste and Spent Solvent Disposal. The site visits conducted during this study underscored the need for proper solid and liquid waste disposal facilities in British Columbia. Users of chlorinated solvents are generally faced with a dilemma of how to properly dispose of sludges and spent solvents. Disposal method options provided by suppliers are:

- o transportation of solvent to licensed reclaimers in the U.S. (there are no such reclaimers in B.C.),
- o incineration in approved facilities (commercial incinerators for such purposes are not available in B.C.),
- o evaporation of small quantities,
- o landfill burial in compliance with local, state, provincial, or federal regulations (approved landfills are not available in B.C.).

Advice provided to users by Provincial and Federal pollution control agencies on disposal is generally oriented towards landfill burial at an EPA-approved landfill in the U.S. Of nine users interviewed for this study:

- o One definitely sent sludges to an approved U.S. land disposal site and solvents for recovery to a U.S. reclaimer.
- o One contracted a local disposal firm which claimed to send the sludges to an approved U.S. site. However this claim is doubtful.
- o Two contracted other local disposal firms and the ultimate disposal methods were unknown.
- o One exposed the sludges to the open air to volatilize the solvents, with subsequent disposal of the remaining grease materials in the municipal dump. (This method was mentioned by a supplier to be very common.)

- o One, a dry cleaner, placed carbon cartridges in a dry cleaning unit to recover all residual solvent, and subsequently the cartridges were disposed in a municipal landfill.
- o Another dry cleaner disposed of small quantities (100 ml/week) of still bottoms in a municipal landfill.
- o Two other users claimed to have no solid or liquid wastes because the solvents were used to formulate other products. However, one of the users had many drums of heavy metal-containing waste materials at hand because no decision had been made provincially or locally on the acceptability of the materials for disposal in B.C. landfill sites.

Solvents must be of specific quality to be considered acceptable for reclamation. Solvents considered to be "too dirty" for reclamation would have to be disposed by other means. As mentioned earlier in this report, a feasibility study for a solvent recovery facility is being undertaken by Harrisons and Crosfield.

The implications of current disposal practices to the B.C. environment are uncertain. A brief review of ground water analyses and landfill leachate studies in B.C. revealed no evidence of analyses for chlorinated solvents. The only facilities available for environmentally acceptable disposal and recovery of chlorinated solvents used in British Columbia are located in the United States. The inability of Canadian provincial and federal authorities, and the public to allow, encourage, and/or provide such facilities in British Columbia is of great concern to industry. With the availability of the sites for disposal, Canadian authorities are not pressed for the establishment of disposal facilities in British Columbia. If, however, U.S. authorities in some way discourage further importation of Canadian wastes, the situation would have to change drastically. It is recommended that planning for disposal facilities in B.C. should be expedited, rather than awaiting political policy changes in the United States.

3.4.3 Predicted Trends. Trends of use for specific solvents were discussed in Section 3.1.5. The dry cleaning industry predicts continued usage of perchloroethylene. The product is considered the best solvent for use in dry cleaning. The volumes sold in B.C. are expected to decrease due to improved process equipment. The paint industry has virtually eliminated the use of chlorinated solvents because of their expense. Other organic solvents such as xylene and toluene are used for oil-based paints, however the general trend is towards latex water-based products.

The metal cleaning industry in the Vancouver area finds trichloroethylene a more favorable solvent, in terms of effectiveness, than trichloroethane. Alternatives are being sought, including consideration of the more expensive freons. It should be noted that our assessment of the metal cleaning industry differs from the assessment of Dow Chemical personnel who predict increasing usage of trichloroethane.

Methylene chloride is used primarily by paint strippers who have ambivalent impressions of its effectiveness and desirability. Alternatives to methylene chloride are being sought by the plastic refurbisher included in this study.

3.4.4 Economic Incentives for Control. Some of the economic incentives for control have already been described. These incentives were based on the rapid rising costs of the chlorinated solvents. During the study, users and distributors frequently mentioned the burdens imposed by the Canadian taxation system which limit investments for more effective process and solvent recovery equipment. As an example, the following costs are associated with the purchase of any equipment in British Columbia:

- o basic cost,
- o transportation costs (usually new dry cleaning equipment is obtained from Italy or the United States),
- o Federal duty (12.1% machine tax on all equipment, unlike the United States where provisions are made for low duty on pollution control equipment),

- o Federal Sales Tax (9%-which may be reduced if the equipment is considered as energy conservation equipment),
- o Provincial Sales Tax (6%),
- o Municipal Equipment Tax (approximately 1.5% annually, with 10% depreciation allowed per year).

The most frequent bone of contention was the municipal tax which was considered a "final straw" for taxation and a deterrent to investment in British Columbia. In principle, pollution control equipment is not subject to municipal tax. However, the tax exempt category is only applicable to equipment which prevents releases outside of a building (e.g., a scrubber or chemical precipitation equipment for wastewater treatment). A "sniffer" such as used in dry cleaning is not considered pollution control equipment and thus subject to tax because it is categorized as necessary for "worker protection rather than pollution control". The industry regards these views of the British Columbia Assessment Board as unreasonable.

3.4.5 Industry Regulatory Agency Liaison and Future Regulatory Requirements. This study indicated that manufacturers, distributors and users are conscientiously self-regulating emissions of the selected chlorinated solvents in British Columbia. It is suggested that further regulations are not required.

A more essential requirement expressed by the industry, is the need for a different approach by government agencies with responsibilities for pollution control. Industry representatives continually stressed the need for government agencies to work with industry to resolve problems rather than acting only to identify problems and impose deadlines for remedial actions. In the view of the industry, government representatives are considered increasingly as antagonists, with minimal appreciation of the efforts required for a business to remain viable. In the words of one user "we should be happy to see that Mr. X from Waste Management Branch or EPS or WCB is coming for a visit. Instead, we would rather lock our doors and shut the lights off". Among the positive suggestions of industry regarding industry-regulatory agency liaison were:

- o Government should have experts who are extremely knowledgeable about particular processes and who can recommend what remedial actions to take.
- o Government requirements should be consistent. The views of individuals within an agency or of agencies should not vary regarding requirements of industry. Liaison between WMB, EPS, DFO and WCB was considered to be very poor.
- o Requirements of industry should be imposed by individuals who are also cognitive of business viability.

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ACKNOWLEDGEMENTS

Ms. Melody Farrell had a lead role in initiating this project. Ms. Farrell and Ms. Eva Gerencher obtained, reviewed and assessed much of the background literature for this project. We are grateful for their competence and interest during the study period.

We wish to thank Douglas Wilson of the Environmental Protection Service (Pacific Region), who as scientific authority, provided us with his good patience and well thought-out scientific comments throughout the study.

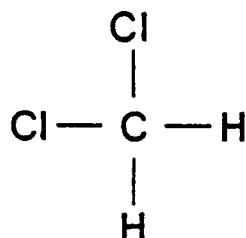
Recognition must also be given to the individuals who suffered through the slings and arrows of report preparation. These individuals include Leslie Borleske and Marilyn Richter, and from E.V.S. Consultants Ltd. - Sarah Irwin, Marla Mees, and Paul Wheeler.

APPENDIX I

REVIEW OF PHYSICAL AND BIOLOGICAL PROPERTIES,
AND ENVIRONMENTAL FATES OF METHYLENE CHLORIDE,
TRICHLOROETHYLENE, PERCHLOROETHYLENE
AND 1,1,1-TRICHLOROETHANE*

*Reference list at back of Appendix I

Methylene Chloride



CAS NO. 75-09-2
TSL NO. PA 80500

Alternate Names

Methylene chloride
Methylene dichloride
Methane dichloride
Methylene bichloride
Dichloromethane

Physical Properties

The general physical properties of dichloromethane are as follows.

Molecular weight (Weast, 1977)	84.94
Melting point (Weast, 1977)	-95°C
Boiling point at 760 torr (Weast, 1977)	39.75°C
Vapor pressure at 20°C (Pearson and McConnell, 1975)	362.4 torr
Solubility in water at 25°C	13,200 to 20,000 mg/L
Log octanol/water partition coefficient (Hansch et al., 1975)	1.25

Biological Properties

Aquatic Species	Freshwater (U.S. EPA, 1978)	
Fathead minnow	96-h LC50	193,000-310,000 ug/L
Bluegill	96-h LC50	224,000 ug/L
Daphnia magna	48-h LC50	224,000 ug/L

EPA Ambient Water Quality Criteria-Freshwater

4,000 ug/L	24 h average
9,000 ug/L	at any time

Environmental Exposure

During the National Organics Monitoring Survey (U.S. EPA, 1978), methylene chloride was positively detected in 15 of 109 drinking water samples obtained throughout the U.S. The mean concentration of the positive values was 6.1 ug/L.

Air emission samples which were analyzed for methylene chloride were restricted to workplace samples.

Environmental Fate

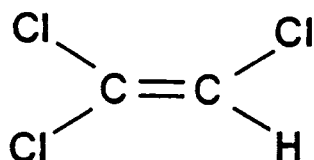
See following table (Callahan and Slimak, 1979).

Summary of Aquatic Fate of Dichloromethane

Environmental Process	Summary Statement	Rate	Half-Life (t _{1/2})	Confidence of Data
Photolysis	Probably not significant in aquatic systems, but may occur in the stratosphere.	-	-	Medium
Oxidation ^a	The predominant fate of this compound appears to be attack by hydroxyl radicals in the troposphere; oxidation in water is not important.	$1.04 \times 10^{-13} \text{ cm}^3 \text{ sec}^{-1}$	0.30 years ^b	Medium
Hydrolysis	Probably not a significant fate.	$1.9 \times 10^{-8} \text{ sec}^{-1} \text{ c}$	417 days	Medium
Volatilization	Primary transport process from the aquatic environment.	-	27 minutes ^d	Medium
Absorption	Probably not significant.	-	-	Low
Bioaccumulation	Probably does not significantly bioaccumulate in organisms.	-	-	Low
Biotransformation/Biodegradation	Probably occurs but at an extremely slow rate.	-	-	Low

- The predominant environmental process which is thought to determine the fate of the compound.
- Reported as a lifetime of 0.30 years.
- Hydrolysis rate is probably a minimum rate.
- Half-lives are on the order of several minutes to a few hours, depending on the degree of agitation; the stated rate is based on the experimental results of Dilling (1977) and Dilling et al. (1975) using a stirred container.

Trichloroethylene



Alternate Name

Trichloroethylene
Ethylene trichloride
Ethinyl trichloride (plus
numerous commercial
names)
Tri-Clene
Trichloroethene

CAS NO. 79-01-6
TSL NO. KX 45500

Physical Properties

The general physical properties of trichloroethylene are given below.

Molecular weight (Weast, 1977)	131.39
Melting point (Weast, 1977)	-73°C
Boiling point at 760 torr (Weast, 1977)	87°C
Vapor pressure at 20°C (Pearson and McConnell, 1975)	57.9 torr
Solubility in water at 20°C (Pearson and McConnell, 1975)	1100 mg/L
Log octanol/water partition coefficient (Leo et al., 1971)	2.29

Biological Properties

Aquatic Species - Freshwater (EPA, 1978)

Fathead minnow	96-h LC50	40,700 ug/L
Bluegill	96-h LC50	44,700 ug/L
Daphnia magna	48-h LC50	85,200 ug/L
Bluegill (loss of equilibrium)	96-h EC50	21,900 ug/L

EPA Ambient Water Quality Criteria - Freshwater

1,500 ug/L	24 h average
3,400 ug/L	at any time

Aquatic Species - Saltwater (EPA, 1978)

Lack of toxicity information, therefore, no EPA Criteria for saltwater species.

No Canadian criteria or standards.

Human and Animal Health

Permissible concentrations in air:

American Conference of Governmental Industrial Hygienists
(8 h time accepted over 40 h workweek):

268 mg/m³ (50 ppm)

B.C. Workers' Compensation Board:

8 h limit:

535 mg/m³ (100 ppm)

15 min limit:

800 mg/m³ (150 ppm)

Examples of effects: (Fuller, 1976)

- o decreased performance in psychophysiological tests upon exposure to 1000 ppm for 2 hours
- o death at 8000 ppm
- o headache, dizziness, fatigue, disturbed sleep, loss of appetite, alcohol intolerance at varied concentrations (20 ppm) for 3-6 years exposure

Trichloroethylene reportedly caused liver cancer in mice which were forced-fed massive doses. Rats did not develop cancer. Identification of trichloroethylene as carcinogen controversial. In 1980, the EPA Science Advisory Board Subcommittee on Airborne Carcinogens refused to accept the EPA Carcinogen Assessment Group's conclusion that trichloroethylene should be regulated as a carcinogen (Dow, 1983).

Environmental Exposures

During National Organics Monitoring Survey (U.S. EPA), trichloroethylene was detected in: 4 of 112 drinking water samples obtained throughout the U.S. in March, 1976, with mean concentrations of 11 ug/L in the positive detections; 28 of 113 cities in May-July samples with a 21 ug/L mean concentration in the 28 samples; and, 19 of 105 cities during November-January samplings, with a 1.3 ug/L average in the 19 samples (EPA, 1978).

Fuller (1976) estimated ambient trichloroethylene concentrations to be 11 nanograms/m³ in air and 0.6 nanograms/L in water. Concentrations in air of one industrial area were estimated to be 86 nanograms/m³.

Environmental Fate

See following table.

Summary of Aquatic Fate of Trichloroethene

Environmental Process	Summary Statement	Rate	Half-Life (t _{1/2})	Confidence of Data
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Photolysis	Probably does not occur since photo-oxidation destroys trichloroethene before it can reach the stratosphere, which is the region above the ozone layer where direct photolysis could occur.	-	-	High
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Oxidation ^a	Photooxidation in the troposphere appears to be the predominant fate of this compound; photooxidation in the aquatic environment occurs at a slow rate; direct oxidation at ambient conditions does not occur in the aquatic or atmospheric environment.	$3 \times 10^{-12} \text{ cm}^3 \text{ sec}^{-1}$	-4 days ^b	High
------------------------	--	---	----------------------	------

Hydrolysis	Probably occurs too slowly to be a significant fate process.	$0.065 \text{ months}^{-1c}$	10.7 months	High
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Volatilization	The primary transport process.	-	~20 minutes ^d	High
----------------	--------------------------------	---	--------------------------	------

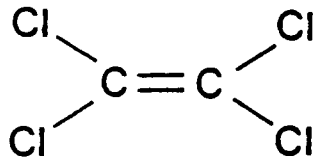
Sorption	Probably not important.	-	-	Medium
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Bioaccumulation	There is evidence of some bioaccumulation by marine organisms, but there is no evidence of biomagnification up the food chain.	-	-	Medium
-----------------	--	---	---	--------

Biodegradation	There is evidence that metabolic products of trichloroethene from higher organisms can be biodegraded by microorganisms in sea water.	-	-	Medium
----------------	---	---	---	--------

- The predominant environmental process which is thought to determine the fate of the compound.
- Reported as a lifetime of $\sim 3.7 \times 10^5$ seconds, corresponding to a lifetime of about 4 days.
- Hydrolysis rate is probably a maximum rate.
- Half-lives are on the order of several minutes to a few days, depending on the degree of agitation; the value presented was determined under conditions of continuous mechanical stirring at 200 rpm.

Perchloroethylene



CAS NO. 127-18-4
TSL NO KX 38500

Alternate Names

Perchloroethylene
Ethylene tetrachloride
Tetrachloroethylene
Perchloroethene
Tetrachloroethene
"Perc"

Physical Properties

The general physical properties of perchloroethylene are given below.

Molecular weight (Weast, 1977)	165.83
Melting point (Verschueren, 1977)	-22.7°C
Boiling point at 760 torr (Weast, 1977)	121°C
Vapor pressure at 20°C (Pearson and McConnell, 1975)	14 torr
Solubility in water at 20°C	150 to 200 mg/l*
Log octanol/water partition coefficient (Neely et al., 1974)	2.88

Biological Properties

Aquatic Species - Freshwater (EPA, 1978)

Fathead minnow	96-h LC50	18,400 ug/L
Bluegill	96-h LC50	12,900 ug/L
Daphnia magna (water flea)	48-h LC50	17,700 ug/L
Fathead minnow (loss of equilibrium)	96-h LC50	14,400 ug/L

EPA Ambient Water Quality Criteria - Freshwater

310 ug/L	24 h average
700 ug/L	at any time

Epidemiological studies of drycleaning workers have found no evidence of deleterious effects of perchloroethylene on worker health or behavioural performance (DHEW, 1977).

Environmental Exposures

During the U.S. EPA National Organics Monitoring Survey, drinking waters of 9 cities of 105 had detectable perchloroethylene concentrations. The maximum concentration was 3.1 ug/L and the median of the nine samples was 0.81 ug/L (U.S. EPA, 1978).

Concentrations of perchloroethylene in air varied from 0.2 to 10.6 ppb in New York City, 0.1 to 4.5 ppb in Houston, and 0.1 to 2.2 ppb in Detroit (Evans, 1979).

Environmental Fate

See following table.

Summary of Aquatic Fate of Tetrachloroethene

Environmental Process	Summary Statement	Rate	Half-Life ($t_{1/2}$)	Confidence of Data
-----------------------	-------------------	------	-------------------------	--------------------

Photolysis	Probably does not occur. Photo-oxidation destroys tetrachloroethene before it can reach the stratosphere, which is the region above the ozone layer where direct photolysis could occur.	-	-	High
------------	--	---	---	------

Oxidation ^a	Photooxidation in the troposphere appears to be the predominant fate of this compound; photooxidation in the aquatic environment occurs at a slow rate; direct oxidation at ambient conditions does not occur in the aquatic or atmospheric environment.	$1.3 \times 10^{-12} \text{ cm}^3 \text{ sec}^{-1}$ $1.7 \times 10^{-13} \text{ cm}^3 \text{ molecule}^{-1} \text{ sec}^{-1}$	^b ~10 days	High
------------------------	--	--	-----------------------	------

Hydrolysis	Probably occurs too slowly to be a significant fate process.	^c 0.079 months	8.8 months	Medium
Volatilization	The primary transport process.	-	^d ~20-30 minutes	High
Sorption	Probably not important.	-	-	Medium
Bioaccumulation	There is evidence of bioaccumulation by marine organisms, but there is no evidence of biomagnification up the food chain.	-	-	Medium
Biodegradation/ Biotransformation	There is evidence that metabolic products of tetrachloroethene from higher organisms can be biodegraded by microorganisms in sea water.	-	-	Medium

- a. The predominant environmental process which is thought to determine the fate of the compound.
- b. Reported as a lifetime of $\sim 8.5 \times 10^5$ seconds, corresponding to a lifetime of about 10 days.
- c. Hydrolysis rate is probably a maximum rate.
- d. Half-lives are on the order of several minutes to a few hours, depending on the degree of agitation. This half-life is based on a stirring rate of 200 rpm in the experimental systems of Dilling (1977) and Dilling et al. (1975).

Examples of effects (Lapp, 1980)

- o above 250 ppm, dizziness, uncoordination and headaches may occur
- o epidemiological study showed workers exposed to 150 ppm for periods of 1-6 years had no adverse effects
- o death at 7000 ppm

No carcinogenic effects were observed in mice or rats force-fed 1,1,1-trichloroethane (Dow, 1983).

Environmental Exposures

Detection of trichloroethane in drinking water have been minimal. Lapp (1980) reported only one of 14 cities in U.S. which had detectable concentrations in drinking water. The concentration was 17 ug/L.

Concentrations in air were positive in 27% of the sampling sites. The concentrations were less than 5 ppb (Lapp, 1980)

Environmental Fate

See following table.

Summary of Aquatic Fate of 1,1,1-Trichloroethane

Confidence
of Data

Half-Life
($t_{1/2}$)

Summary
Statement

Environmental
Process

Rate

Medium

Probably not significant in aquatic systems. Photolysis-oxidation in the stratosphere appears to be important for this compound.

Oxidation^a Not a significant fate process for this compound in aquatic systems; photooxidation in the troposphere is the predominant fate process.

from 8.2×10^{-13} $\text{cm}^3 \text{sec}^{-1}$ to 2.8×10^{-14} $\text{cm}^3 \text{sec}^{-1}$

from 1.1 years^b to 8 years

High

Medium

Probably occurs too slowly to be a significant fate process.

6 months

0.12 month^{-1c}

Medium

The primary transport process from the aquatic environment.

-20-25 minutes^d

Low

Probably not important.

-

Low

Probably not important.

-

Low

Probably occurs at an extremely slow rate.

-

- a. The predominant environmental process which is thought to determine the fate of the compound.
- b. Reported as lifetimes (time for reduction to 1/e of original concentration) of 1.1 to 8 years.
- c. Should be considered as a maximum rate.
- d. Half-lives are on the order of several minutes to a few hours, depending on the degree of agitation; the reported rate was determined in a stirred system.

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APPENDIX II

EXAMPLES OF MATERIAL SAFETY DATA SHEETS
FOR METHYLENE CHLORIDE, TRICHLOROETHYLENE,
PERCHLOROETHYLENE AND 1,1,1-TRICHLOROETHANE

MATERIAL SAFETY DATA SHEET



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information supplied by the
Dow Quality Assurance Data Center

DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

M A T E R I A L S A F E T Y D A T A S H E E T P A G E : 1

EFFECTIVE DATE: 27 JAN 82

PRODUCT CODE: 55590

PRODUCT NAME: METHYLENE CHLORIDE, TECH.

MSD: 0009

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

METHYLENE CHLORIDE, ESSENTIALLY : 100 :

SECTION 1

PHYSICAL DATA

BOILING POINT: 104F (39.8C) : SOL. IN WATER: 2.0G/100G @ 25C
VAP PRESS: 340 MMHG @ 20C : SP. GRAVITY: 1.320 @ 25/25C
VAP DENSITY (AIR=1): 2.93 : % VOLATILE BY VOL: 100 (ESSENT.)

APPEARANCE AND ODOR: COLORLESS LIQUID

SECTION 2

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NONE : FLAMMABLE LIMITS
METHOD USED: TCC, ICC, COC : LFL: 14.8% @ 25C UFL: 22% @ 25C

EXTINGUISHING MEDIA: WATER FOG.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: PRESSURE DEMAND SELF-CONTAINED RESPIRATORY EQUIPMENT. FORMS FLAMMABLE VAPOR-AIR MIXTURES AT TEMPERATURES ABOVE AMBIENT. LOWER TEMPERATURES INCREASE THE DIFFICULTY OF GETTING IT TO IGNITE.

SECTION 3

REACTIVITY DATA

STABILITY: HYDROLYSIS PRODUCING SMALL AMOUNTS OF HYDROCHLORIC ACID POSSIBLE WITH GROSS WATER CONTAMINATION.

INCOMPATIBILITY: ALUMINUM, POSSIBLY SODIUM, POTASSIUM, AND MAGNESIUM.

HAZARDOUS DECOMPOSITION PRODUCTS: OPEN FLAMES AND WELDING ARCS CAN CAUSE THERMAL DEGRADATION WITH THE EVOLUTION OF HYDROGEN CHLORIDE AND VERY SMALL AMOUNTS OF PHOSGENE AND CHLORINE.

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4

SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SMALL SPILLS: MOP UP, WIPE UP OR SOAK UP IMMEDIATELY. REMOVE TO OUT OF DOORS.
LARGE SPILLS: EVACUATE AREA. CONTAIN LIQUID; TRANSFER TO CLOSED

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 27 JAN 82
 PRODUCT (CONT'D): METHYLENE CHLORIDE, TECH.

PRODUCT CODE: 55590
 MSD: 0009

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): (CONTINUED)
 METAL CONTAINERS, KEEP OUT OF WATER SUPPLY.

DISPOSAL METHOD: (IN ORDER OF PREFERENCE) SEND SOLVENT TO LICENSED RECLAIMER,
 INCINERATION, EVAPORATION OF VERY SMALL QUANTITIES, OR APPROVED
 LANDFILL BURIAL IN COMPLIANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS.
 DUMPING INTO SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER IS STRONGLY
 DISCOURAGED, AND MAY BE ILLEGAL.

SECTION 5 HEALTH HAZARD DATA

INGESTION: LOW SINGLE DOSE ORAL TOXICITY. LD50 MALE RATS 2524 MG/KG.

EYE CONTACT: CAUSES PAIN AND MODERATE IRRITATION, AND POSSIBLE TRANSIENT
 CORNEAL INJURY.

SKIN CONTACT: SHORT CONTACT - NO IRRITATION. PROLONGED OR FREQUENTLY
 REPEATED CONTACT - MODERATE IRRITATION. IF CONFINED TO SKIN - MAY
 CAUSE A BURN.

SKIN ABSORPTION: IS ABSORBED, BUT IS LOW IN TOXICITY BY THIS ROUTE.

INHALATION: OSHA STANDARD IS 500 PPM (1975). ACGIH TLV IS 100 PPM.

EFFECTS OF OVEREXPOSURE: CARBOXYHEMOGLOBIN LEVELS MAY BE ELEVATED.
 INCREASING SIGNS OF ANESTHESIA ABOVE 900 PPM IN THE ATMOSPHERE.
 CAN CAUSE DEATH IF TOO MUCH IS BREATHED.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY FOR
 15 MINUTES. REFER TO MEDICAL PERSONNEL.

SKIN: WASH OFF IN FLOWING WATER. WASH CLOTHING BEFORE REUSE.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR
 TRANSPORT TO MEDICAL FACILITY. IF RESPIRATION STOPS GIVE MOUTH-
 TO-MOUTH RESUSCITATION.

INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN AND/OR TRANSPORT
 TO EMERGENCY FACILITY.

NOTE TO PHYSICIAN:

EYES: MAY CAUSE IRRITATION. STAIN FOR EVIDENCE OF CORNEAL
 INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION
 FREQUENTLY. CONSULT OPHTHALMOLOGIST.

(CONTINUED ON PAGE 3)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 27 JAN 82
 PRODUCT (CONT'D): METHYLENE CHLORIDE, TECH.

PRODUCT CODE: 35590
 MSD: 0009

SECTION 6 FIRST AID--NOTE TO PHYSICIAN (CONTINUED)

NOTE TO PHYSICIAN: (CONTINUED)

SKIN: MAY CAUSE IRRITATION. CHRONIC EXPOSURE MAY CAUSE DEFATTING TYPE OF DERMATITIS. IF RASH IS PRESENT, TREAT AS ANY CONTACT DERMATITIS.

RESPIRATORY: ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. ADMINISTER OXYGEN IF AVAILABLE.

ORAL: MAY CAUSE CHEMICAL PNEUMONIA IF ASPIRATED INTO LUNGS. DANGER OF CHEMICAL PNEUMONIA MUST BE WEIGHED AGAINST TOXICITY WHEN CONSIDERING EMPTYING STOMACH. IF LAVAGE IS PERFORMED SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.

SYSTEMIC: MAY CAUSE INCREASE IN CARBOXYHEMOGLOBIN LEVELS. MAY INCREASE MYOCARDIAL IRRITABILITY. AVOID EPINEPHRINE OR SIMILAR DRUGS IF AT ALL POSSIBLE. CONSULT STANDARD LITERATURE. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDES.

RESPIRATORY PROTECTION: APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR IS RECOMMENDED.

PROTECTIVE CLOTHING: NO SPECIAL PROTECTIVE CLOTHING NEEDED.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS. EYE WASH STATIONS AND SAFETY SHOWERS SHOULD BE READILY AVAILABLE.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: EXERCISE REASONABLE CARE AND CAUTION. AVOID BREATHING VAPORS. STORE IN COOL PLACE. VAPORS OF THIS PRODUCT ARE HEAVIER THAN AIR AND WILL COLLECT IN LOW AREAS SUCH AS PITS, DECREASERS, STORAGE TANKS, AND OTHER CONFINED AREAS. DO NOT ENTER THESE AREAS WHERE VAPORS OF THIS PRODUCT ARE SUSPECTED UNLESS SPECIAL BREATHING APPARATUS IS USED AND AN OBSERVER IS PRESENT FOR ASSISTANCE. DO NOT PRESSURE PRODUCT OUT OF VESSEL OR TRANSPORT CONTAINER WITH AIR.

ADDITIONAL INFORMATION: 27 JAN 82 REVISED FROM 22 SEP 81 --
 SECTIONS 3, 5 AND 6.

CONTINUED ON PAGE 4)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

M A T E R I A L S A F E T Y D A T A S H E E T P A G E : 4

EFFECTIVE DATE: 27 JAN 82
PRODUCT (CONT'D): METHYLENE CHLORIDE, TECH.

PRODUCT CODE: 55590
MSD: 0009

LAST PAGE

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

CONSULT THE DOW CHEMICAL COMPANY FOR FURTHER INFORMATION.

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MATERIAL SAFETY DATA SHEET



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DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

MATERIAL SAFETY DATA SHEET PAGE: 1
DOW CHEMICAL CANADA INC., SARNIA, ONTARIO N7T 7M1 EMERGENCY PHONE: 519-339-7711

EFFECTIVE DATE: 22 OCT 82

PRODUCT CODE: 56530

PRODUCT NAME: NEU-TRI (R) SOLVENT

MSD: 0168

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

TRICHLOROETHYLENE (NOMINAL) : 99 :

SECTION 1

PHYSICAL DATA

BOILING POINT: 189F (87C) : SOL. IN WATER: 0.1 G/100G @ 25C
VAP PRESS: 60 MMHG @ 20C : SP. GRAVITY: 1.46 @ 25/25C
VAP DENSITY (AIR=1): 4.53 : % VOLATILE BY VOL: 100 (ESSENTIALLY)

APPEARANCE AND ODOR: COLORLESS LIQUID.

SECTION 2

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NONE : FLAMMABLE LIMITS
METHOD USED: TCC : LFL: 7.8VOL% 100CUFL: 52 VOL% 100C

EXTINGUISHING MEDIA: WATER FOG. 8.0 VOL% 25C 10.5 VOL% 25C

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: PRESSURE DEMAND SELF-CONTAINED RESPIRATORY PROTECTION. STRONG UNPLEASANT ODOR. NOT CONSIDERED A FLAMMABLE LIQUID UNDER NORMAL INDUSTRIAL USE CONDITIONS. AUTOIGNITION TEMPERATURE IS 788F, 420C.

SECTION 3

REACTIVITY DATA

STABILITY: AVOID OPEN FLAMES, WELDING ARCS, OR OTHER HIGH TEMPERATURE SOURCES WHICH INDUCE THERMAL DECOMPOSITION.

INCOMPATIBILITY: STRONG BASES: CAUSTIC SODA, CAUSTIC POTASH.

HAZARDOUS DECOMPOSITION PRODUCTS: INVOLVEMENT IN FIRE FORMS HYDROGEN CHLORIDE AND VERY SMALL AMOUNTS OF PHOSGENE & CHLORINE.

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4

SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS: SMALL SPILLS:
MOP UP, WIPE UP OR SOAK UP IMMEDIATELY. REMOVE TO OUT OF DOORS.
LARGE SPILLS: EVACUATE AREA. CONTAIN LIQUID; TRANSFER TO CLOSED METAL CONTAINERS. KEEP OUT OF WATER SUPPLY.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 22 OCT 82
PRODUCT (CONT'D): NEU-TRI (R) SOLVENT

PRODUCT CODE: 56530
MSD: 0168

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

DISPOSAL METHOD: (IN ORDER OF PREFERENCE) SEND SOLVENT TO LICENSED RECLAIMER, INCINERATION, EVAPORATION OF VERY SMALL QUANTITIES, OR APPROVED LANDFILL BURIAL IN COMPLIANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS. DUMPING INTO SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER IS STRONGLY DISCOURAGED, AND MAY BE ILLEGAL.

SECTION 5 HEALTH HAZARD DATA

EYE: PAIN AND IRRITATION, BUT NO (OR ONLY MINOR) CORNEAL INJURY LIKELY.

SKIN CONTACT: SHORT CONTACT - NO IRRITATION. PROLONGED OR REPEATED CONTACT - MODERATE IRRITATION AND DRYING MAY OCCUR. IF CONFINED TO SKIN - PAIN AND A BURN.

SKIN ABSORPTION: VERY LOW TOXICITY; NOT A HAZARD.

INGESTION: LOW ACUTE ORAL TOXICITY IN RATS, LD50 > 4 G/KG. BUT MAY BE MODERATELY TOXIC IN HUMANS.

INHALATION: ACGIH TLV IS 50 PPM AND OSHA GUIDE IS 100 PPM.

SYSTEMIC & OTHER EFFECTS: ANESTHESIA. PROLONGED OR REPEATED EXPOSURES TO LEVELS OVER 100 PPM - POSSIBLE ORGANIC INJURY. CAN CAUSE DEATH IF TOO MUCH IF BREATHED. STUDIES WITH TOXIC DOSES GIVEN BY STOMACH TUBE INDICATED A CARCINOGENIC RESPONSE IN ONE STRAIN OF LABORATORY MICE, BUT NOT IN OTHER LABORATORY ANIMALS EXPOSED BY INGESTION OR INHALATION. THE PREPONDERANCE OF INFORMATION INDICATES TRICHLOROETHYLENE IS NOT LIKELY TO BE A CARCINOGEN IN MAN.

SECTION 6 FIRST AID

EYES: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY FOR FIFTEEN MINUTES. REFER TO MEDICAL PERSONNEL.

SKIN: IN CASE OF CONTACT, IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING. CALL A PHYSICIAN. WASH CLOTHING BEFORE REUSE.

INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN OR TRANSPORT TO EMERGENCY FACILITY.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. IF RESPIRATION STOPS, GIVE MOUTH-TO-MOUTH RESUSCITATION. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.

NOTE TO PHYSICIAN:

EYES: MAY CAUSE MODERATE IRRITATION. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.

SKIN: MAY CAUSE MILD IRRITATION. CHRONIC EXPOSURE MAY CAUSE DEFATTING TYPE OF DERMATITIS. TREAT AS ANY CONTACT DERMATITIS.

(CONTINUED ON PAGE 3)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 22 OCT 82
PRODUCT (CONT'D): NEU-TRI (R) SOLVENT

PRODUCT CODE: 56530
MSD: 0168

SECTION 6 FIRST AID (CONTINUED)

NOTE TO PHYSICIAN: (CONTINUED)

RESPIRATORY: MAY CAUSE DRUNKENNESS. ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP. MECHANICAL SUPPORT OF RESPIRATION MAY BE NEEDED.

ORAL: MAY CAUSE CHEMICAL PNEUMONIA IF ASPIRATED INTO LUNGS. IF LAVAGE IS PERFORMED, SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL. LOW IN TOXICITY.

SYSTEMIC: MAY INCREASE MYOCARDIAL IRRITABILITY. AVOID EPINEPHRINE OR SIMILAR ACTING DRUGS IF AT ALL POSSIBLE. LIVER AND KIDNEY INJURY POSSIBLE WITH OVEREXPOSURE. MAY CAUSE NAUSEA OR VOMITING. ALCOHOL CONSUMED BEFORE AND AFTER EXPOSURE MAY INCREASE INJURY. NO SPECIFIC ANTIDOTE. CONSULT STANDARD LITERATURE. SUPPORTIVE CARE.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDE.

RESPIRATORY PROTECTION: APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR IS RECOMMENDED.

PROTECTIVE CLOTHING: NONE REQUIRED.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: HANDLE WITH REASONABLE CARE. AVOID BREATHING VAPORS. STORE IN COOL PLACE. VAPORS OF THIS PRODUCT ARE HEAVIER THAN AIR AND WILL COLLECT IN LOW AREAS SUCH AS PITS, DEGREASERS, STORAGE TANKS, AND OTHER CONFINED AREAS. DO NOT ENTER THESE AREAS WHERE VAPORS OF THIS PRODUCT ARE SUSPECTED UNLESS SPECIAL BREATHING APPARATUS IS USED AND AN OBSERVER IS PRESENT FOR ASSISTANCE.

ADDITIONAL INFORMATION: TLV, SECTION 5 REVISED ON 22 OCT 82.

LAST PAGE

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MATERIAL SAFETY DATA SHEET



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DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

MATERIAL SAFETY DATA SHEET PAGE: 1
DOW CHEMICAL CANADA INC. SARNIA, ONTARIO N7T 7K1 EMERGENCY PHONE: 519-339-7711

EFFECTIVE DATE: 03 OCT 80

PRODUCT CODE: 25202

PRODUCT NAME: BOMPER (R) SOLVENT

MSD: 0190

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :

PERCHLOROETHYLENE (MINIMUM) : 99 :

SECTION 1

PHYSICAL DATA

BOILING POINT: 250F (121.1C) : SOL. IN WATER: 0.015 G/100G 25C
VAP PRESS: 13 MMHG @ 20C : SP. GRAVITY: 1.619 @ 25/25C
VAP DENSITY (AIR=1): 5.76 : % VOLATILE BY VOL: 100 (ESSENTIALLY)

APPEARANCE AND ODOR: COLORLESS LIQUID.

SECTION 2

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NONE : FLAMMABLE LIMITS
METHOD USED: TDC, TCC, COC : LFL: NONE UFL: NONE

EXTINGUISHING MEDIA: NON-FLAMMABLE MATERIAL.

SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: PRESSURE DEMAND
SELF-CONTAINED RESPIRATORY EQUIPMENT. NO AUTOIGNITION TEMPERATURE.

SECTION 3

REACTIVITY DATA

STABILITY: AVOID OPEN FLAMES, WELDING ARCS, OR OTHER
HIGH TEMPERATURE SOURCES WHICH INDUCE THERMAL DECOMPOSITION.

INCOMPATIBILITY: ----

HAZARDOUS DECOMPOSITION PRODUCTS: INVOLVEMENT IN FIRE FORMS HYDROGEN
CHLORIDE AND SMALL AMOUNTS OF PHOSGENE AND CHLORINE.

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4

SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS: SMALL LEAKS -
MOP UP, WIPE UP, OR SOAK UP IMMEDIATELY. REMOVE TO OUT OF DOORS.
LARGE SPILLS - EVACUATE AREA. CONTAIN LIQUID; TRANSFER TO CLOSED
METAL CONTAINERS. KEEP OUT OF WATER SUPPLY.

DISPOSAL METHOD: (IN ORDER OF PREFERENCE) SEND SOLVENT TO LICENSED RECLAIMER,
INCINERATION, EVAPORATION OF VERY SMALL QUANTITIES, OR APPROVED
LANDFILL BURIAL IN COMPLIANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS.

(CONTINUED ON PAGE 2)

FOR FURTHER INFORMATION, CONTACT YOUR LOCAL DOW CHEMICAL COMPANY.

EFFECTIVE DATE: 03 OCT 80
PRODUCT (CONT'D): DOWPER (R) SOLVENT

PRODUCT CODE: 25202
MSD: 0190

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

DISPOSAL METHOD: (CONTINUED)

DUMPING INTO SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER IS STRONGLY DISCOURAGED, AND MAY BE ILLEGAL.

SECTION 5 HEALTH HAZARD DATA

EYE: PAIN AND IRRITATION, BUT NO CORNEAL INJURY SHOULD OCCUR.

SKIN CONTACT: SHORT CONTACT - NO IRRITATION. PROLONGED OR FREQUENTLY REPEATED CONTACT - MODERATE IRRITATION AND DRYING. IF CONFINED TO SKIN - PAIN AND IRRITATION, EVEN A BURN.

SKIN ABSORPTION: LOW TOXICITY. LD50 (RABBIT) GREATER THAN 10 G/KG.

INGESTION: LOW IN SINGLE DOSE ORAL TOXICITY. LD50 (RAT) GREATER THAN 5000; (MOUSE) IN RANGE OF 8000 TO 11000 MG/KG.

INHALATION: ACGIH TLV AND OSHA STANDARD IS 100 PPM.

SYSTEMIC & OTHER EFFECTS: POSSIBLE ORGANIC INJURY FROM PROLONGED OR REPEATED EXPOSURES; IRRITATION; CENTRAL NERVOUS SYSTEM DEPRESSION. CAN CAUSE DEATH IF TOO MUCH IS BREATHED. ONE LIFETIME STUDY WITH TOXIC DOSES OF PERCHLOROETHYLENE GIVEN BY STOMACH TUBE INDICATED A CARCINOGENIC RESPONSE IN LABORATORY MICE, BUT NOT IN RATS EXPOSED BY INGESTION OR INHALATION. THE PREPONDERANCE OF INFORMATION INDICATES PERCHLOROETHYLENE IS NOT LIKELY TO BE A CARCINOGEN IN MAN. EMBRYOTOXICITY WAS SEEN IN ANIMALS AT DOSES TOXIC TO THE MATERNAL ANIMAL.

SECTION 6 FIRST AID

EYES: IRRIGATION OF THE EYES IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE.

SKIN: WASH OFF IN FLOWING WATER OR SHOWER 15 MINUTES. CONSULT MEDICAL. THOROUGHLY AIR DRY OR WASH GROSSLY CONTAMINATED CLOTHES BEFORE REUSE.

INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN OR TRANSPORT TO EMERGENCY FACILITY.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. IF RESPIRATION STOPS, GIVE MOUTH-TO-MOUTH RESUSCITATION. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.

NOTE TO PHYSICIAN:

EYES: MAY PRODUCE CONJUNCTIVITIS. STAIN FOR EVIDENCE OF CORNEAL INJURY.

SKIN: CHRONIC EXPOSURE MAY PRODUCE DEFATTING TYPE OF DERMATITIS. TREAT AS ANY CONTACT DERMATITIS.

RESPIRATORY: MODERATE IRRITANT. BRONCHODILATORS, EXPECTORANTS AND ANTITUSSIVES MAY BE OF HELP. OXYGEN MAY BE HELPFUL. MECHANICAL SUPPORT OF RESPIRATION MAY BE NEEDED.

(CONTINUED ON PAGE 3)

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EFFECTIVE DATE: 03 OCT 80
PRODUCT (CONT'D): DOWPER (R) SOLVENT

PRODUCT CODE: 25202
MSL: 0190

SECTION 6 FIRST AID (CONTINUED)

NOTE TO PHYSICIAN: (CONTINUED)

ORAL: MAY CAUSE CHEMICAL PNEUMONITIS IF ASPIRATED INTO LUNGS.

PRODUCT LOW IN TOXICITY. DANGER OF CHEMICAL PNEUMONIA MUST BE WEIGHED AGAINST TOXICITY. IF LAVAGE IS PERFORMED, SUGGEST ENDO-TRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.

SYSTEMIC: ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. MAY INCREASE MYOCARDIAL IRRITABILITY. AVOID EPINEPHRINE OR SIMILAR ACTING DRUGS IF AT ALL POSSIBLE. MAY CAUSE NAUSEA OR VOMITING. ALCOHOL CONSUMED BEFORE OR AFTER EXPOSURE MAY INCREASE INJURY. NO SPECIFIC ANTIDOTE. LIVER AND KIDNEY CHANGES SHOWN IN ANIMAL STUDIES. CONSULT STANDARD LITERATURE.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDE.

RESPIRATORY PROTECTION: NIOSH APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR AS APPROVED BY NIOSH IS RECOMMENDED.

PROTECTIVE CLOTHING: NONE REQUIRED.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: HANDLE WITH REASONABLE CARE AND CAUTION. AVOID BREATHING VAPORS. VAPORS OF THIS PRODUCT ARE HEAVIER THAN AIR AND WILL COLLECT IN LOW AREAS SUCH AS PITS, DEGREASERS, STORAGE TANKS, AND OTHER CONFINED AREAS. DO NOT ENTER THESE AREAS WHERE VAPORS OF THIS PRODUCT ARE SUSPECTED UNLESS SPECIAL BREATHING APPARATUS IS USED AND AN OBSERVER IS PRESENT FOR ASSISTANCE.

ADDITIONAL INFORMATION: 03 OCT 80 REVISIONS OF 16 OCT 79 --
SECTIONS 4, 5, AND 6.

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DOW CHEMICAL CANADA INC., Sarnia, Ontario N7T 7K7

EMERGENCY PHONE NUMBERS: SARNIA (519) 339-3711; FORT SASKATCHEWAN (403) 998-8282

EFFECTIVE DATE: 10 JUN 81

PRODUCT CODE: 16831

PRODUCT NAME: CHLOROTHENE (R) VG - CS SOLVENT

MSD: 1494

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS) : % :
1,1,1-TRICHLOROETHANE (MINIMUM) : 94.5 :

SECTION 1

PHYSICAL DATA

BOILING POINT: 165F (74C) : SOL. IN WATER: 0.07G/100G @ 25C
VAP PRESS: 100 MMHG @ 20C; 13.3 K PA: SP. GRAVITY: 1.314 @ 25/25C
VAP DENSITY (AIR=1): 4.55 : % VOLATILE BY VOL: 100 (ESSEN.)
APPEARANCE AND ODOR: COLORLESS LIQUID.

SECTION 2

FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: NONE : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: T.O.C., T.C.C., C.O.C. : LFL: 7.5% @ 25C UFL: 15% @ 25C
EXTINGUISHING MEDIA: WATER FOG.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: SELF-CONTAINED
RESPIRATORY EQUIPMENT. NOT CONSIDERED A FLAMMABLE LIQUID HAZARD
UNDER AMBIENT TEMPERATURE USE CONDITIONS.

SECTION 3

REACTIVITY DATA

STABILITY: AVOID OPEN FLAMES, WELDING ARCS OR OTHER HIGH
TEMPERATURE SOURCES WHICH INDUCE THERMAL DECOMPOSITION.
INCOMPATIBILITY: WATER - SLOW HYDROLYSIS PRODUCES CORROSIVE ACID.
HAZARDOUS DECOMPOSITION PRODUCTS: HYDROGEN CHLORIDE AND VERY SMALL
AMOUNTS OF PHOSGENE AND CHLORINE.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4

SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): SMALL LEAKS:
MOP UP, WIPE UP OR SOAK IMMEDIATELY. REMOVE TO OUT OF DOORS. LARGE
SPILLS: EVACUATE AREA. CONTAIN LIQUID; TRANSFER TO CLOSED METAL
CONTAINERS. KEEP OUT OF WATER SUPPLIES.
DISPOSAL METHOD: (IN ORDER OF PREFERENCE) SEND SOLVENT TO LICENSED RECLAIMER,
INCINERATION, EVAPORATION OF VERY SMALL QUANTITIES, OR APPROVED LANDFILL
BURIAL IN COMPLIANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS. DUMPING
INTO SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER IS STRONGLY
DISCOURAGED, AND MAY BE ILLEGAL.

(CONTINUED ON PAGE 2)

(R) INDICATES A TRADEMARK OF THE DOW CHEMICAL COMPANY

EFFECTIVE DATE: 10 JUN 81
 PRODUCT (CONT'D): CHLOROTHENE (R) VG - CS SOLVENT

PRODUCT CODE: 16831
 MSD: 1494

SECTION 5 HEALTH HAZARD DATA

INGESTION: VERY LOW TOXICITY. LD50 (LABORATORY ANIMALS) RANGES FROM 8.3 TO 15.0 G/KG.
 EYE CONTACT: MILD IRRITATION, BUT NO CORNEAL INJURY LIKELY.
 SKIN CONTACT: SHORT CONTACT - NO IRRITATION. PROLONGED OR FREQUENT EXPOSURE - MINOR IRRITATION.
 SKIN ABSORPTION: VERY LOW TOXICITY. LD50 (RABBITS) - 24 HOUR EXPOSURE - GREATER THAN 15 G/KG.
 INHALATION: OSHA GUIDE AND ACGIH TLV IS 350 PPM.
 EFFECTS OF OVEREXPOSURE: ANESTHETIC EFFECTS - MAY OCCUR IN THE RANGE OF 1000 PPM. CAN CAUSE DEATH IF TOO MUCH IS BREATHED.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATION OF THE EYE IMMEDIATELY WITH WATER FOR FIVE MINUTES IS GOOD SAFETY PRACTICE.
 SKIN: CONTACT WILL PROBABLY CAUSE NO MORE THAN IRRITATION. WASH OFF IN FLOWING WATER OR SHOWER. WASH CLOTHING BEFORE REUSE.
 INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. IF RESPIRATION STOPS, GIVE MOUTH-TO-MOUTH RESUSCITATION. ADMINISTER OXYGEN IF AVAILABLE. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY.
 INGESTION: DO NOT INDUCE VOMITING. CALL A PHYSICIAN AND/OR TRANSPORT TO EMERGENCY FACILITY.

NOTE TO PHYSICIAN:

EYES: MAY CAUSE CONJUNCTIVITIS. STAIN FOR EVIDENCE OF CORNEAL INJURY.
 SKIN: MAY CAUSE MILD IRRITATION. CHRONIC EXPOSURE MAY CAUSE DEFATTING TYPE OF DERMATITIS. TREAT AS ANY CONTACT DERMATITIS. NOT LIKELY TO BE ABSORBED IN ACUTELY TOXIC AMOUNTS.
 RESPIRATORY: ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP.
 ORAL: LOW IN TOXICITY. MAY CAUSE REACTION SIMILAR TO PETROLEUM OR PETROLEUM-LIKE SOLVENT. DANGER OF CHEMICAL PNEUMONIA MUST BE WEIGHED AGAINST TOXICITY WHEN CONSIDERING EMPTYING THE STOMACH. IF LAVAGE IS PERFORMED, SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.
 SYSTEMIC: MAY INCREASE MYOCARDIAL IRRITABILITY. AVOID EPINEPHRINE OR SIMILAR ACTING DRUGS IF AT ALL POSSIBLE. CONSULT STANDARD LITERATURE. NO SPECIFIC ANTIDOTE. TREATMENT BASED ON THE SOUND JUDGMENT OF THE PHYSICIAN AND THE INDIVIDUAL REACTIONS OF THE PATIENT.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDE.
 RESPIRATORY PROTECTION: NONE NORMALLY NEEDED. APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR IS RECOMMENDED. CARTRIDGE RESPIRATORS ARE NOT RECOMMENDED EXCEPT FOR EVACUATION.
 PROTECTIVE CLOTHING: NO SPECIAL PROTECTIVE CLOTHING NEEDED.
 EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: HANDLE WITH REASONABLE CARE. AVOID BREATHING VAPORS. STORE IN A COOL DRY PLACE. VAPORS OF THIS PRODUCT ARE HEAVIER THAN AIR AND WILL COLLECT IN LOW AREAS SUCH AS PITS, DEGREASERS, STORAGE TANKS, AND OTHER CONFINED AREAS. DO NOT ENTER THESE AREAS WHERE VAPORS OF THIS PRODUCT ARE SUSPECTED UNLESS SPECIAL BREATHING APPARATUS IS USED AND AN OBSERVER IS PRESENT FOR ASSISTANCE.
 ADDITIONAL INFORMATION: NEW

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APPENDIX III

BRIEF REVIEW OF PERTINENT LITERATURE

(REFERENCE IS MADE AS FREQUENTLY AS POSSIBLE TO NTIS MICROFICHE IDENTIFICATION NUMBERS. MICROFICHE CAN BE OBTAINED READILY FROM UBC OR BCIT LIBRARIES.)

BRIEF REVIEW OF LITERATURE

1.0 CASE STUDIES

1.1 Health Hazard Evaluation Determination.

Report #75-195-396. NTIS MF PB-273 779

United Airlines Maintenance Base, San Francisco International Airport -
NIOSH-TR-HHE-75-195-396.

Investigation of worker complaints of eye and throat irritation and head congestion. Predominant cause found to be stripper (Methylene chloride) application to aircraft by hose and scraping off by hand with trowels and brushes.

1.2 Health Hazard Evaluation Determination.

NIOSH-TR-HHE-80-74-714. NTIS MF PB81-168486

Standard Publishing Company, Cincinnati, Ohio.

Worker complaints about eye and throat irritation. Cause was a stencil remover containing perchloroethylene and some fatty acids. A mercury vapor lamp degraded perchloroethylene to phosgene and hydrogen chloride. Poor ventilation system also enhanced problems.

1.3 Health Hazard Evaluation Determination.

NIOSH-HE-78-77-659. NTIS MF PB80-163165

R. L. Polk Co., Cincinnati, Ohio.

Graphic services company with worker complaints of eye, mouth and skin irritation and recurring headaches. Several solvents used in process including methylene chloride, 1,1,1 trichloroethane and perchloroethylene for multilith cleaning. Ventilation, cotton gloves and disposal of gauze pads were found to be causes of problems.

- 1.4 Health Hazard Evaluation Determination.
NIOSH-TR-HHE-75-150-378. NTIS MF PB-273 731
Reinell Boats, Missouri.

Fibreglass boat manufacturer with worker complaints of eye-burning, nose and throat irritation and headaches. Styrene and isocyanate found to be prime exposure chemicals with less exposure to acetone and methylene chloride. Impervious gloves recommended for workers who use methylene chloride to clean MDI foaming guns.

- 1.5 Health Hazard Evaluation Determination.
NIOSH-TR-HHE-76-42-407. NTIS MF PB-274 227
Sibley Engineering and Manufacturing Co., Arkansas.

Manufacturer of precision parts for aircraft and missiles. Use of trichloroethane as vapor degreaser in automatic screw manufacturing machine. Symptoms not severe in workers. Report reviews recommended respiratory equipment for use in presence of TCE spill. Concentrations of TCE in air were determined at various portions of the plant.

- 1.6 Health Hazard Evaluation Determination.
NIOSH-TR-HHE-80-87-708. NTIS MF PB81-168460
Harowe Servo Controls Inc.

Manufacturer of AC motor parts. Workers near trichloroethane vapor degreaser reported skin, eye and upper respiratory irritation. Despite TCE levels below NIOSH recommended levels, symptoms were evident in workers. Extensive review of operations and design of vapor degreasers.

2.0 CRITERIA FOR STANDARDS

2.1 Criteria for Recommended Standard - Occupational Exposure to 1,1,1 Trichlorethane.

NIOSH-76/184. NTIS MF PB-267 069

Reviews known human health related problems, worker safety precautions, labelling, protective equipment, handling/storage procedures, equipment maintenance, uses, concentrations found in air in the places of use, and recommends operation procedures for degreasers.

2.2 Guide for Recommended Standard - Occupational Exposure to Methylene Chloride.

NIOSH-76-138. NTIS MF PB81-227027

Reviews known toxicity data, outlines labelling procedures, worker safety precautions, handling/storage/loading procedures, uses, previously known worker case studies, concentrations found in places of use, and recommends maximum levels in workplace.

2.3 Development Document for Effluent Limitations Guidelines and Standards for the Paint Formulating Point Source Category.

EPA 440/1-79/049-b.

Reviews paint formulating processes, characteristics of wastewaters and control processes for reducing emissions. Methylene chloride was found to be major contaminant of plants reporting discharges.

2.4 Perchloroethylene: Dry Cleaners - Background Information for Proposed Standards.

EPA 450/3-79/029-a.

Reviews dry cleaning processes, results of air and water monitoring, and technologies to reduce emissions.

2.5 Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems.

EPA 450/2-78/050. NTIS MF PB-290 613

Much the same as 2.4. Reviews processes, identified problem areas and controls. Emissions (water, air and solids) are quantified. Reviews release rates for various plants, on a process-by-process basis.

2.6 Current Intelligence Bulletin 20 - Tetrachloroethylene (Perchloroethylene).

NIOSH-78-112. NTIS MF PB-278 055

Suggests the 1976 limit of 50 ppm might not be adequate. Outlines NIOSH sponsored research studies on TCE. Recommends control by exposure monitoring, engineering controls, respiratory protection and personal protective equipment.

2.7 Proposed biological threshold limit values for industrial exposure to trichloroethylene vapor. Etienne Guberan, M.D., 1977. Scand. j. work environ. and health 3 (1977) 80-90.

A study using mathematical models to simulate the pharmacokinetics of inhaled trichloroethylene vapor. Results of metabolite excretion among individuals exposed to 100 ppm steady concentration of TRI agree with findings of similar studies among TRI workers in industry.

2.8 Standards of performance for new stationary sources; perchloroethylene dry cleaners.

Fed. Regist. 25 Nov. 1980. 45 (229). 78175-80.

Reviews use of PCE in drycleaning industry. Standards are proposed to limit emissions of volatile organic compounds from new, modified and reconstructed dry cleaners, which would require installation of carbon absorbers and dry-to-dry machines.

- 2.9 Ambient Water Quality Criteria: Tetrachloroethylene
U.S. EPA, NTIS MF PB-292 445

Reviews toxicity of tetrachloroethylene to aquatic species and suggests criteria.

- 2.10 Ambient Water Quality Criteria: Trichloroethylene
U.S. EPA, NTIS MF PB-292 443

Reviews toxicity of trichloroethylene to aquatic species and suggests criteria.

- 2.11 Ambient Water Quality Criteria: Halomethanes
U.S. EPA, NTIS MF PB-296 797

Reviews toxicity of halomethanes, including methylene chloride to aquatic species and suggests criteria.

3.0 EPIDEMIOLOGICAL STUDIES

- 3.1 A Behavioural and Neurological Evaluation of Dry Cleaners Exposed to Perchloroethylene (PCE).
DHEW/PUB/NIOSH-77/214.

Presents results of tests conducted on drycleaners exposed to PCE. Results conclude that neurological deficits are attributable to Stoddarts solvent, not PCE. No evidence was found of deleterious effects of PCE on worker health or behavioural performance.

- 3.2 Results of the Controlled Exposure of Human Females to the Vapor of Methylene Chloride.
NIOSH/MCOW/ENVM-MC-74-3. NTIS MF PB82-164872

Results of controlled exposure of human females to MC vapor. Neurological behavioural and medical tests revealed no deleterious effects on the test subjects.

- 3.3 Health of Workers Exposed to 1,1,1 Trichloroethane: A Matched Pair Study, 1978. C.G. Kramer, M.D. et al. Archives of Environ. Health (33), 1978, pgs. 331-342.

Epidemiological study of 151 matched pairs of employees in adjacent textile plants, one of which used 1,1,1-trichloroethane as a cleaning solvent. Data and sensitive statistical comparison techniques did not reveal any clinically pertinent finding associated with 1,1,1 trichloroethane.

- 3.4 Pulmonary - Hematologic Studies on Humans during exposure to Methylene Chloride. NTIS MF PB82-151697
NIOSH-MCOW-ENVM-MC-74-4.

Results of a study exposing 4 individuals over 6 week periods to varying concentrations (0-500 ppm) of methylene chloride indicated that methylene chloride exposure had no effect on pulmonary integrity or ventilation. However hemoglobin saturation with carbon monoxide during MC exposure increased Hb affinity for oxygen and no adaptation occurred during exposure to restore Hb affinity for oxygen to normal.

- 3.5 Extent of exposure survey of methylene chloride DHHS (NIOSH) Publ. (US) 1980. 81-131. 53 pgs.

Survey to determine MC exposure potential in triacetate manufacturing, coffee decaffeination and aircraft paint stripping facilities. Included are background information on production and uses, toxicity and human exposure standards, production processes, control efforts, health and safety programs, air sampling data and recommendations.

- 3.6 Effects of chlorinated solvents in a metal working plant. Vavazzalo, Franco, AES 1981 3(2). 84-9.

Discusses needs for control of chlorinated solvents in metal working plants. Details economics of control implementation . Stresses need for objective research.

- 3.7 Epidemiological study of hepatic tumor incidence in subjects working with trichloroethylene II. Negative result of retrospective studies in dry cleaners.

Malek, Bohuslav et al. *Prac. Lek*, 1979. 31(4). 124-6.

Result of a study of liver cancer incidence among 86% of all men who had spent at least 1 year in drycleaning operations. Exposure was considerable as reflected by urine concentrations of trichloroacetic acid; however, no incidence of liver cancer and 10% incidence of other organ cancers were detected.

- 3.9 A clinical, neurophysiological and behavioral study of female workers
Maroni, M., et al. *Scand. j. work environ. and health* 3(1977) 16-22.

Female workers were exposed to 1,1,1-trichloroethane levels from 110 to 990 ppm. Absence of a manifest neurotoxic effect of 1,1,1-trichloroethane under specific work conditions was found. Unfavorable work conditions were a more prominent factor in complaints.

- 3.10 Proposed biological threshold limit values for industrial exposure to trichloroethylene vapor.

Guberan, E. *Scand. j. work environ. and health* 3(1977) 80-90.

Reviews biological effects on workers exposed to various levels of trichloroethylene. Discusses need to design monitoring which will consider times when "toxic threshold" is exceeded in addition to time-weighted concentrations.

- 3.11 Epidemiological study on hepatic tumor incidence in subjects working with trichloroethylene. I. negative result of retrospective studies in subjects with primary liver carcinoma.

Novotna, E. et al. *Prac. Lek*. 1979, 31(4), 121-3.

Attempted to determine if subjects with primary liver cancer were ever exposed to trichloroethylene as a cause.

4.0 OTHER DOCUMENTS OF INTEREST

- 4.1 Volatile Organic Compound (VOC) Species Data Manual.
EPA 450/4-80-015. NTIS MF PB81-119455

One section describes the vapor degreasing process and variations in design. Emissions with the use of various control options are given on the basis of pounds emissions per ton metal cleaned.

- 4.2 Proceedings of a Conference on Methyl Chloroform (Trichloroethane) and Other Halocarbon Pollutants held at Washington, D.C., on February 27-28, 1979. NTIS MF PB80-142433

Conference was sponsored to assess environmental implications of increased usage of trichloroethane. One paper of interest, entitled "An Assessment of Trichloroethylene, Methyl Chloroform and Perchloroethylene". Reviews environmental levels of TCE and PCE reported in the literature and possible effects on the environment. Controversy re: health assessment of TCE and PCE illustrated during heated discussion period. Another paper entitled "Environmental fate of methyl chloroform", discusses residence time of MC in the troposphere and its impact on the stratosphere. Paper concludes that the impact of MC is less than that of chlorofluoromethanes.

- 4.3 Air Pollution Assessment of Tetrachloroethylene.
MTR-7143. NTIS MF PB-256 731

Reviews toxicity, environmental concentrations, usage, mass balance, and precautions for use. Concludes that TCE is not an environmental hazard except in the workplace.

- 4.4 Air Pollution Assessment of Trichloroethylene. Mitre Corporation Report for U.S. EPA. NTIS MF PB 256730

Extensive report on toxicity of TCE, exposure of workers at various industries to TCE, uses, and control measures. An excellent background document.

- 4.5 City of Vancouver Industrial Waste Inventory, 1977.

Quantifies annual solvent waste generation for 1977 from a number of selected user industries such as electroplaters, machine shops, plastics and rubber manufacturers, paint manufacturers, drycleaners etc. in the city of Vancouver.

- 4.6 Hazardous Toxic and Nuisance Wastes Survey - 1978.
Greater Vancouver Sewerage and Drainage District.

- 4.7 Compilation of Air Pollutant Emission Factors.
U.S. EPA - Second Edition - 1975.

- 4.8 Measurement of Perchloroethylene in Ambient Air
EPA 600/4-79-047. NTIS MF PB80-144678

Presents methods for determination of PCE in ambient air and meteorological data summaries of PCE in large metropolitan U.S. areas with either; large populations, PCE producing plants, or a large number of metal degreasing operations.

- 4.9 Evaluation of Emission Test Methods for Halogenated Hydrocarbons.
EPA 600/4-79-025. NTIS MF PB-298247

Discussion of methods for analytical determinations of chlorinated hydrocarbons, methods for halogenated hydrocarbon storage and reviews effects of heating and cooling solvents.

5.0

Are trichloroethane based substitutes safer than xylene.

K.J. Reid and F.J. Young. Medical Laboratory Sciences (1981), 38.
Letters to the Editor, pgs. 145-149.

Raises questions about toxicity of 1,1,1 TCE in the presence of heat.
Letter suggests that a more critical appraisal of substitutes whose main
component is TCE is required.