NICNAS

National Industrial Chemicals Notification and
Assessment Scheme

Tetrachloroethylene

Priority Existing Chemical Assessment Report No. 15

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Preface

This assessment was carried out under the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). This Scheme was established by the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act), which came into operation on 17 July 1990.

The principal aim of NICNAS is to aid in the protection of people at work, the public and the environment from the harmful effects of industrial chemicals.

NICNAS assessments are carried out in conjunction with Environment Australia and the Therapeutic Goods Administration, which carry out the environmental and public health assessments, respectively.

NICNAS has two major programs: the assessment of the health and environmental effects of new industrial chemicals prior to importation or manufacture; and the other focussing on the assessment of chemicals already in use in Australia in response to specific concerns about their health and/or environmental effects.

There is an established mechanism within NICNAS for prioritising and assessing the many thousands of existing chemicals in use in Australia. Chemicals selected for assessment are referred to as Priority Existing Chemicals.

This Priority Existing Chemical report has been prepared by the Director (Chemicals Notification and Assessment) in accordance with the Act. Under the Act manufacturers and importers of Priority Existing Chemicals are required to apply for assessment. Applicants for assessment are given a draft copy of the report and 28 days to advise the Director of any errors. Following the correction of any errors, the Director provides applicants and other interested parties with a copy of the draft assessment report for consideration. This is a period of public comment lasting for 28 days during which requests for variation of the report may be made. Where variations are requested the Director's decision concerning each request is made available to each respondent and to other interested parties (for a further period of 28 days). Notices in relation to public comment and decisions made appear in the *Commonwealth Chemical Gazette.*

In accordance with the Act, publication of this report revokes the declaration of this chemical as a Priority Existing Chemical, therefore manufacturers and importers wishing to introduce this chemical in the future need not apply for assessment. However, manufacturers and importers need to be aware of their duty to provide any new information to NICNAS, as required under section 64 of the Act.

For the purposes of section 78(1) of the Act, copies of Assessment Reports for New and Existing Chemical assessments may be inspected by the public at the library of the National Occupational Health and Safety Commission (NOHSC). Summary Reports are published in the *Commonwealth Chemical Gazette*, which are also available to the public at the NOHSC library.

Copies of this and other Priority Existing Chemical reports are available on the NICNAS website. Hardcopies are available from NICNAS either by using the prescribed application form at the back of this report, or directly from the following address:

GPO Box 58

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AUSTRALIA

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Other information about NICNAS (also available on request) includes:

- NICNAS Service Charter;
- information sheets on NICNAS Company Registration;
- information sheets on the Priority Existing Chemicals and New Chemical assessment programs;
- safety information sheets on chemicals that have been assessed as Priority Existing Chemicals;
- subscription details for the NICNAS Handbook for Notifiers; and
- subscription details for the Commonwealth Chemical Gazette.

More information on NICNAS can be found at the NICNAS Web site:

http://www.nicnas.gov.au

Other information on the management of workplace chemicals can be found at the website of the National Occupational Health and Safety Commission:

http://www.nohsc.gov.au

Overview

The chemical tetrachloroethylene (CAS No. 127-18-4) was declared a Priority Existing Chemical for preliminary assessment under the *Industrial Chemicals (Notification and Assessment) Act 1989* on 7 April 1998. The focus of the assessment was on the use of and exposure to the chemical in Australia.

For this assessment, the physico-chemical, toxicological and environmental properties of tetrachloroethylene have been summarised from peer-reviewed hazard assessments by international organisations such as the OECD Existing Chemicals Programme (SIDS), the International Agency for Research on Cancer (IARC), the Agency for Toxic Substances and Disease Registry (ATSDR) and the United States Environmental Protection Agency (US EPA).

Tetrachloroethylene manufacture in Australia ceased in 1991. In the period 1995 to 1999 imports have decreased from about 4200 tonnes to 2500 tonnes per year. The declining use is in line with declining use worldwide. The chemical is primarily imported and used in its 'pure' form, in industrial processes, with approximately 80% of the import volume used in the drycleaning industry. The other major uses (based on volume) of tetrachloroethylene identified in this report are automotive products, textile manufacture, as a solvent in chemical maskants and in the coal industry. Small quantities of formulated industrial and consumer products containing tetrachloroethylene are also imported.

The acute toxicity of tetrachloroethylene in animals and humans is low following inhalation and ingestion, and the chemical causes skin irritation and mild eye irritation. High acute exposure levels result in central nervous system (CNS) effects in animals and CNS effects and respiratory irritation in humans. Repeated exposure results in target organ toxicity in the kidney in rats, and the liver in mice. It induces liver tumours in mice, kidney tumours in male rats and mononuclear cell leukaemia in male and female rats. The relevance of these animal tumours to humans continues to be debated internationally. Subtle liver effects have been observed in humans following repeated exposure. There is some evidence of adverse effects on reproduction in animals exposed to several hundred ppm, but inconclusive data as to this effect in humans.

In Australia tetrachloroethylene is classified as a carcinogen category 3 (R40), carrying with it a possible risk of adverse effects.

Tetrachloroethylene readily degrades in air and evaporates rapidly from soil and surface water. It could however leach through sandy soil and therefore reach groundwater where it may persist for a number of years. Bioaccumulation is unlikely to be significant. Its toxicity to fish and invertebrates is considered to be slight to moderate, but the chemical appears to be highly toxic to some invertebrates depending on their life stage. Chloritic effects have been observed in the leaves of terrestrial plants exposed to 1.7 ppb tetrachloroethylene over several months.

Drycleaning, of garments and fabrics in Australia, can be viewed as essentially an enclosed process. The extent of worker exposure depends largely on how specific sites undertake the associated tasks of transferring the chemical into the machine, cleaning filters and removing still waste.

The Drycleaning Institute of Australia (DIA) has developed guidelines for the safe use of tetrachloroethylene in the drycleaning industry.

The automotive products expose workers to the chemical at formulation and during end-stage use. Formulation is in partly and fully enclosed systems, however, usage would be in open processes in workshops. These products are in aerosol form and inappropriate use could lead to high acute exposure, however chronic exposure is likely to be low as end use is intermittent. The manufacture of textiles requires that the fibres be cleaned of residual oils. Tetrachloroethylene is used on its own or in mixtures to strip the oils with the processes being either partly or fully enclosed. Chemical maskants is an area where tetrachloroethylene is used for its solvent properties and the volumes are large. The particular process described in this report is fully enclosed with limited worker exposure. Testing of coal samples for density of the ore uses tetrachloroethylene as part of a mixture of chemicals. The process is open, with local exhaust ventilation to remove fumes. There is the potential for high exposures, however, operators wear personal protective equipment, including respirators.

Transportation of tetrachloroethylene is regulated under the Australian Dangerous Goods Code (ADG Code) as adopted by the States and Territories. In accordance with the Standard for the Uniform Scheduling of Drugs and Poisons (SUSDP), the label of a container or package of a retail product containing tetrachloroethylene must carry warning statements and safety directions. Products containing tetrachloroethylene supplied to a workplace and classified as hazardous substances should include risk and safety phrases on the label.

State and Territory legislation does not specifically identify tetrachloroethylene rather its use is regulated by adopting national codes classifying the chemical as a hazardous substance and dealing with hazardous substances generally in occupational health and safety, dangerous goods, poisons and environmental legislation. Discharge levels of tetrachloroethylene and tetrachloroethylene contaminated waste are determined by local water authorities.

Use of products containing the chemical, by the public, is likely to be intermittent as would indirect exposure from entering drycleaning establishments and storing drycleaned garments in the home. As such total public exposure is likely to be low.

There are no Australian data on tetrachloroethylene levels in surface water or soil and limited data for air concentrations. Environmental release from current uses will result in tetrachloroethylene partitioning mainly to the atmosphere with some release to surface water possible via sewers. In a worst case scenario, predicted atmospheric concentrations for urban air of 0.8 ppb and 4.5 ppb for point source release may be calculated. Based on this modelling there is the potential for adverse impacts on terrestrial plants. However, based on the current use pattern, environmental risk is considered to be minimal in Australia.

Although occupational exposure levels are generally low, tetrachloroethylene is a possible human carcinogen and it is therefore recommended that industry continue to strive to improve their process and engineering controls. In particular, it is recommended that the coal testing laboratories aim to reduce tetrachloroethylene levels in the atmosphere and aerosols containing tetrachloroethylene should not be used by workers on a regular basis.

On the basis of the known hazards, assessed exposure information and current controls, NICNAS does not recommend a full (risk) assessment at this time.

Contents

LIST OF TABLES

LIST OF FIGURES

Abbreviations

ACCC	Australian Competition and Consumer Commission
ATSDR	Agency for Toxic Substances and Disease Registry
ACGIH	American Conference of Governmental Industrial Hygienists
ADG Code	Australian Code for the Transport of Dangerous Goods by Road and Rail
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
BCF	Bioconcentration factor
BUA	Beratergremium fur Umweltrelevante Altstoffe (Advisory Committee on Existing Chemicals of Environmental Relevance)
C	centigrade
CAS	Chemical Abstracts Service
cm	centimetre
cm^3	cubic centimetre
CNS	central nervous system
d	day
DIA	Drycleaning Institute of Australia Limited
DIRB	Drycleaning Industry Registration Board
DIRS	Drycleaning industry regulation standard
EA	Environment Australia
EC50	Median effective concentration
ECETOC	European Centre for Ecotoxicology and Toxicology of Chemicals
EINECS	European Inventory of Existing Commercial Chemical Substances
g	gram
GC	gas chromatography
GGT	gamma glutamyltransferase
h	hour
IARC	International Agency for Research on Cancer
IUPAC	International Union of Pure and Applied Chemistry
Kad	The ratio of sorbed to solution chemical in a water-soil slurry
Kdes	Desorption co-efficient
kg	kilogram
Koc	Adsorption co-efficient based on organic carbon content of a solid phase
Kom	Adsorption co-efficient based on organic matter content of a soil
Koc	octanol/water partition coefficient
kPa	kilopascal
L	litre
LC50	median lethal concentration

LD50	median lethal dose
m^3	cubic metre
ML	megalitre
MSDS	Material Safety Data Sheet
µg	microgram
mg	milligram
mL	millilitre
mm	millimetre
mol	mole
ng	nanogram
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NOHSC	National Occupational Health and Safety Commission
NPI	National Pollutant Inventory
OECD	Organisation for Economic Cooperation and Development
OSHA	Occupational Safety and Health Administration (USA)
Pa	pascals
PEC	predicted environmental concentration
PEL	permissible exposure limit
PPE	personal protective equipment
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
SGOT	serum glutamate oxaloacetate transaminase
SGPT	serum glutamate pyruvate transaminase
SIDS	Screening Information Data Set
STEL	short-term exposure limit
SUSDP	Standard for the Uniform Scheduling of Drugs and Poisons
TCA	trichloroacetic acid
TCAC	trichloroacetyl chloride
TGA	Therapeutic Goods Administration
TWA	time-weighted average
US EPA	United States Environmental Protection Agency
UV	ultraviolet
VECCI	Victorian Employer's Chamber of Commerce and Industry

1. Introduction

1.1 Declaration

The chemical tetrachloroethylene (CAS No. 127-18-4) was declared a Priority Existing Chemical for preliminary assessment under the *Industrial Chemicals (Notification and Assessment) Act 1989* (the Act) on 7 April 1998.

1.2 Scope of the assessment

The Act prescribes which matters may be taken into account and addressed in a preliminary assessment. Risk assessment and risk management are not covered in preliminary assessments. However, as an outcome of a preliminary assessment, the Act requires the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) to determine the significance of the assessment findings for risk. If the findings indicate that there may be a significant potential for risk of adverse health, safety or environmental effects, then a full (risk) assessment may be recommended.

1.3 Objectives

The objectives of this assessment were to:

- determine the uses of tetrachloroethylene in Australia;
- determine the extent of occupational, public and environmental exposure to tetrachloroethylene;
- summarise the adverse health and environmental effects of tetrachloroethylene;
- characterise the properties of tetrachloroethylene;
- determine whether or not the significance for risk of adverse health, safety or environmental effects is such that a full (risk) assessment should be undertaken.

1.4 Sources of information

Relevant scientific data were submitted by applicants and notifiers, obtained from the published literature, or retrieved from other sources. A substantial amount of information was obtained from several comprehensive, peer-reviewed, publications prepared by overseas agencies detailed in section 2.3 of this report.

Information on product specifications, use patterns and occupational and environmental control measures were made available by applicants and notifiers and obtained from site visits.

1.5 Peer review

During all stages of preparation, the report has been subject to internal peer review by NICNAS, Environment Australia (EA) and the Therapeutic Goods Administration (TGA). The hazard summary was based on overseas national and international, peer-reviewed documents.

2. Background

2.1 International perspective

Tetrachloroethylene is a commercially important chlorinated hydrocarbon solvent and chemical intermediate. Known more commonly as perchloroethylene or “perc” the chemical is manufactured throughout the world including the United States, the European Union, Asia and South Africa. Outside Australia it is primarily used as a drycleaning and textile processing solvent and for vapour degreasing in metal cleaning operations.

World demand for tetrachloroethylene has decreased since the mid 1980’s as a result of the phase out of chlorofluorocarbons (where it was the major raw material in the manufacture of the chlorofluorocarbon R113); the use of more efficient drycleaning equipment; and increased reclamation of waste solvent (Kirk-Othmer 1993). For example production in the United States has declined from 547 million pounds in 1983 to 271 million pounds in 1993. The US production trend is mirrored in the European Union, with a decline from 340,800 tonnes in 1986 to 164,000 tonnes in 1994 (OECD, 1996).

In the US approximately 37% of the tetrachloroethylene produced is used as a drycleaning solvent (US EPA, 1998), but of the total chemical used (both imported and domestically produced) about 15% is used in drycleaning, (ATSDR, 1997).

Tetrachloroethylene is produced naturally by several temperate and subtropical marine macroalgae. The natural production from algae “may be of such magnitude that it cannot be neglected in the global atmospheric chlorine budget” (ATSDR, 1997).

2.2 Australian perspective

Tetrachloroethylene is not manufactured in Australia. The chemical was produced by ICI Australia Pty Limited (now Orica Australia) until the end of 1991 at the NSW Botany plant. All Australian industrial requirements for tetrachloroethylene are satisfied now by import either of the pure chemical or in formulated products. The majority of the chemical is used in the drycleaning industry.

2.3 Assessments by other national or international bodies

Tetrachloroethylene has been assessed by several other national or international bodies involved in the review or evaluation of data pertaining to health and environmental hazards posed by chemicals. The following publications have been consulted in the preparation of this report:

- U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, 1997. Toxicological Profile for Tetrachloroethylene (Update) (ATSDR, 1997).
- U.S. Environmental Protection Agency Office of Pollution Prevention and Toxics, 1998. Cleaner Technologies Substitutes Assessment: Professional Fabricare (US EPA, 1998).

- Canadian Departments of Environment and Health, 1993. Processes Priority Substance List Assessment Report-Tetrachloroethylene (CAN, 1993).
- BUA report 139 German Chemical Society Advisory Committee on Existing Chemicals of Environmental Relevance, 1993. Tetrachloroethylene (BUA, 1993).
- Health and Safety Executive of the United Kingdom, 1996. Screening Information Data Set (SIDS) Initial Assessment Report for the OECD Existing Chemicals Programme (OECD, 1996).

OECD SIDS Assessment Report

The OECD SIDS Initial Assessment Report for tetrachloroethylene was agreed to at the 5th SIDS Initial Assessment meeting, in October 1996. At the meeting it was agreed that tetrachlorethylene is considered a low potential environmental risk but there is a need for further work and consideration of risk management measures for human health. The human health recommendation was based on the need for limiting the risks for consumers on the use of coin-operated drycleaning machines.

Building on the OECD hazard assessment, this NICNAS preliminary assessment sets out to establish whether the uses and potential risks of tetrachloroethylene in Australia are similar to the OECD findings.

3. Applicants

Following the declaration of tetrachloroethylene as a Priority Existing Chemical, twenty-three importers of either pure chemical, or products containing the chemical, applied for assessment. Other Applicants comprised interested organisations. The Applicants supplied information on the properties, import quantities and uses of the chemical. In accordance with the *Industrial Chemicals (Notification and Assessment) Act 1989*, NICNAS provided the Applicants with a draft copy of the report for comments during the corrections/variation phase of the assessment. The Applicants were as follows:

Amtrade International Pty Ltd
Level 2, 570 St Kilda Road
Melbourne VIC 3004

Aerospace Technologies of Aust Pty Ltd
226 Lorimer Street
Port Melbourne VIC 3207

Asia Pacific Specialty Chemicals Ltd
15 Park Road
Seven Hills NSW 2147

Australian Council of Trade Unions
393 Swanston Street
Melbourne VIC 3000

Australian Manufacturing Workers Union
3/440 Elizabeth Street
Melbourne VIC 3000

Bio-Scientific Pty Ltd
28 Monro Avenue
Kirrawee NSW 2232

Consolidated Chemical Company
52-62 Waterview Close
Dandenong South VIC 3175

Bronson and Jacobs Pty Ltd
Parkview Drive
Homebush Bay NSW 2140

Crown Scientific Pty Ltd
144 Moorebank Avenue
Moorebank NSW 2178

Elf Atochem (Aust) Pty Ltd
270/280 Hammond Road
Dandenong VIC 3175

GTS Transport & Industrial Supplies
140 Penola Road
Mount Gambier SA 5290

Imatech
7/6 Gladstone Road
Castle Hill NSW 2154

3M Aust Pty Ltd
Dunheved Circuit
St Marys NSW 2760

Merck Pty Ltd
207 Glouster Road
Kilsyth VIC 3137

Orica Pty Ltd
1 Nicholson Street
Melbourne VIC 3000

Peacock & Smith (Sales) Pty Ltd
350 Arden Street
Kingston VIC 3031

Redox Chemicals Pty Ltd
30-32 Redfern Street
Wetherill Park NSW 2164

Selby-Biolab
2 Clayton Road
Clayton VIC 3168

Deltrex Chemicals
7-11 Burr Court
Laverton North VIC 3028

Dow Chemical (Aust) Ltd
Kororoit Creek Road
Altona VIC 3018

Du Pont (Aust) Ltd
49-59 Newton Road
Wetherill Park NSW 2164

DIC International (Aust) Pty Ltd
18-20 Pickering Road
Mulgrave VIC 3170

Sigma-Aldrich
2/14 Anella Avenue
Castle Hill NSW 2154

Solvents Aust Pty Ltd
77 Bassett Street
Mona Vale NSW 2103

Schlumberger Oilfield Aust Pty Ltd
23 Brennan Way
Belmont WA 6104

4. Chemical Identity and Composition

4.1 Chemical name (IUPAC)

Tetrachloroethylene

4.2 Registry numbers

Tetrachloroethylene is listed on the Australian Inventory of Chemical Substances (AICS) as *Ethene, tetrachloro-*

CAS number	127-18-4
EINECS number	204-825-9

4.3 Other names

1,1,2,2-tetrachloroethylene; Ethylene tetrachloride; per; perc; perchlor; perchloroethylene; perk; tetrachloroethene; PCE

4.4 Trade names

Perchloroethylene; DOWPER* Solvent; Perclean; Perc; Percdx; Perchlor; Perkext; Perstabil

4.5 Molecular formula

C_2Cl_4

4.6 Structural formula

$Cl_2C{=}CCl_2$

4.7 Molecular weight

165.83

4.8 Composition of commercial grade product

95% to 99.9%

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* Trademark of the Dow Chemical Company

5. Physical and Chemical Properties

5.1 Physical properties

Tetrachloroethylene is a colourless liquid at room temperature with an ether-like odour. Measurements of odour threshold show great variability with figures ranging from 1.0 ppm to 50.0 ppm (US EPA, 1998; ATSDR, 1997; BUA, 1993).

Table 1 - Physical properties of tetrachloroethylene

Property	Value	Reference
Melting point	-19°C	ATSDR 1997
Boiling point	121°C	ATSDR 1997
Density (at 20°C)	1.6227 g/ml	ATSDR 1997
Vapour density at 101 kPa	5.8kg/m^3	Kirk-Othmer, 1993
Vapour pressure (at 25.0°C)	2.462 kPa	ATSDR 1997
Water solubility (at 25°C)	150 mg/L	ATSDR 1997
Henry's Law constant (at 25°C)	1.8×10^{-2}atm-m^3/mol	ATSDR 1997
Partition coefficient (log Kow)	3.40	ATSDR 1997
Flash point	None	ATSDR 1997
Autoignition temperature	No data	
Explosive limits	No data	

5.2 Chemical properties

Tetrachloroethylene is the most stable of the chlorinated ethylenes and ethanes requiring minimal addition of stabilisers and having no flash point. These properties combined with its solvent properties account for its dominant use in the drycleaning industry.

When water is present with tetrachloroethylene aluminium, iron and zinc are corroded. This corrosion is inhibited by the addition of stabilisers which include acetone, aniline, borates, esters, o-cresol, ethylacetate, hydrazine derivatives, pyrazols, stearates and sulphur dioxide (BUA 1993). When stabilised, tetrachloroethylene is resistant to hydrolysis up to temperatures of 150°C. When stabilisers are not present and tetrachloroethylene is in contact with water for long periods, it slowly hydrolyses to yield trichloroacetic acid and hydrochloric acid.

In the absence of catalysts, air or moisture, tetrachloroethylene is stable to about 500°C. Thermal decomposition, when it occurs, results in the formation of hydrogen chloride and phosgene. In the presence of air or oxygen and ultraviolet radiation, tetrachloroethylene undergoes auto-oxidation to trichloroacetyl chloride.

A number of inorganic materials including sulphur, iodine and aluminium chloride are soluble in tetrachloroethylene to varying degrees. It also dissolves a variety of organic substances such as fats, oils, rubber, tar and resins, but not sugars or proteins. Tetrachloroethylene is miscible with chlorinated organic solvents and most other common solvents (Kirk-Othmer, 1993).

5.3 Conversion factors at 25^0C and 760 mm Hg

1 mg/m^3 = 0.147 ppm

1 ppm = 6.78 mg/m^3

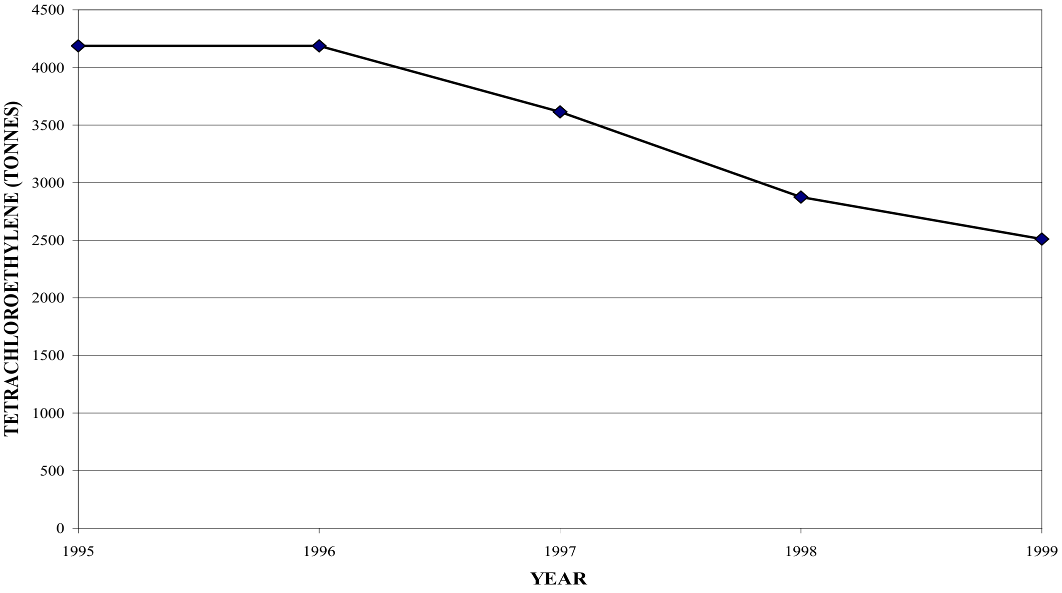
6. Importation, Manufacture and Use

6.1 Importation and manufacture

Tetrachloroethylene is no longer manufactured in Australia.

Tetrachloroethylene is imported as either “pure” chemical or as a constituent of formulated products. Import data was sought from Australian industry by NICNAS for the period 1995 to 1999. During this period the importation volume has fallen from about 4200 to 2500 tonnes per year (see figure 1). Customs data, since 1996, generally reflects the import data provided by industry.

Figure 1 – Importation of Tetrachloroethylene (1995-1999)



The trend has shown a decline over the last five years of between 30% to 40% of total imports which is broadly in line with the experience worldwide. The major reason for the decline is the improvement in drycleaning machine technology. Current drycleaning machinery is more effectively sealed, and recycles the solvent more efficiently.

Importation of analytical grade tetrachloroethylene has risen from 1995, though actual quantities are small.

In 1999, twelve companies imported tetrachloroethylene or products containing tetrachloroethylene. The bulk of tetrachloroethylene is imported as “pure” chemical, which is used as is, or to formulate into products. Imported or locally formulated goods containing tetrachloroethylene are either industrial solvents or cleaning preparations, or products where the chemical is used as a solvent within the product.

6.2 Transport and repackaging

Five companies imported "pure" tetrachloroethylene in 1999. The majority of the chemical is imported by ship in bulk. The remainder of the import volume arrives prepackaged in 200 or 25 litre steel drums, or 4.5 litre glass bottles. Drummed imports are either repackaged or sold as is. Chemical imported in glass bottles is not repackaged. Three of the importers repackage tetrachloroethylene into 20 litre steel drums or 10 litre high-density polyethylene containers. The process of repackaging ranges from partly enclosed, to fully enclosed systems.

6.2.1 Shipment

Importation of bulk chemical by ship is to either Botany in NSW or Coode Island in Victoria where it is transferred from the vessel to a dedicated bulk storage tank located in a bunded compound. Approximately 4 shipments per year are received in this way, 2 each in NSW and Victoria. Steel drums and glass bottle shipments also arrive at Botany or Coode Island as well as other ports around Australia.

6.2.2 Transport

Bulk shipments

At the terminal, product is pumped from the ship's tank(s) to a dedicated storage tank via a permanent wharf pipeline which is dedicated to tetrachloroethylene during the transfer. The chemical is then either pumped from the dedicated storage tank to 200 litre steel drums, or 3000 litre road tankers.

Transfer to 200 litre drums is commenced by decanting 20 litres of the chemical into a bucket to ensure integrity of the product, before the drum fill hose is inserted into the drum bung hole. The drum is placed on scales and chemical added until the exact filled weight is obtained. The 20 litres is put into specified "slops" tanks.

Road tankers are top loaded from the bulk storage tank via a metered pipeline, with emission control measures in place. Tankers are fitted with pipelines having emergency safety features built in and a metered pump allowing delivery of specified amounts of chemical.

The terminal site has a continuously operating automatic vapour extraction system. This system draws air from around hose connections at tanker and drum filling stations, and openings on bulk storage tanks, then through piping to a central carbon bed adsorption system. The air is drawn through the carbon and out an emission stack. The carbon is regularly desorbed of trapped chemical by high pressure steam, and the vapour condensate collected and disposed of through waste collection contractors.

Drums filled at the wharf are delivered from there direct to customers who include drycleaners and other users.

Tankers deliver either to an importer facility where the chemical is packed into 10 litre polythene containers direct from the tanker, for resale, or directly to drycleaners and other users. In the latter case tetrachloroethylene is added to the drycleaning machines internal storage tanks (the most common practice), or added to an external storage drum for later decanting.

Chemical imported in steel drums or glass bottles is transported to the importers' premises.

6.2.3 Importation of mixtures

Imported mixed products containing tetrachloroethylene are an electric motor cleaner (imported by one company) and a carpet cleaner (imported by one company). These products are currently imported in aerosol cans. Transport from the wharf is by truck to the respective importers' premises. These products are not repackaged.

6.3 Overall use

Estimated quantities for the use of tetrachloroethylene and tetrachloroethylene containing products are given in Table 2.

Table 2 – Estimates of tetrachloroethylene usage in 1999

Use	Approximate Quantity (tonnes)	Form of Use
Drycleaning	1900	Pure chemical
Automotive products	105	Locally formulated product
Coal industry	25	Pure chemical
Chemical maskant	25	Pure chemical
Textile scouring	24	Pure chemical & locally formulated products
Film cleaning	15	Pure chemical
Petroleum refining industry	13	Pure chemical
Analytical reagent	< 0.5	Pure chemical
Oil exploration	< 0.5	Pure chemical
Carpet cleaning	< 0.5	Imported formulated product
Other[1]	306	Imported and locally formulated products
Estimated total	**2413 tonnes**	

Note: 1 – includes printing industry, general fabric care, electric motor/parts cleaner and metal degreasing and general metal equipment cleaning solvents.

6.4 Use of pure tetrachloroethylene

6.4.1 Drycleaning

The major use of tetrachloroethylene in Australia is drycleaning. In 1999, approximately 1,900 tonnes of tetrachloroethylene (about 78% of importation) was used in the drycleaning industry.

The drycleaning industry is a service industry for the cleaning of clothes, manchester, and other items made of fibres including household furnishings and curtains. Drycleaning processes garments in a way that avoids saturating fabrics with water. Tetrachloroethylene is the principal solvent used in drycleaning because it does not saturate the fibres of the fabric, so the swelling and shrinking from water is avoided. Also it is used because of its degreasing qualities.

There are two types of drycleaning enterprise: retail sites traditionally located in shopping areas and high capacity commercial/industrial sites. NICNAS conducted site visits to a small number (10) of drycleaning enterprises in NSW. The selection of companies was based on their size to ensure both retail sites and high capacity commercial/industrial sites were covered.

Clothes go through several steps at drycleaning facilities. The general process is similar in all facilities, however, some steps and procedures may vary. There are three basic processes involved in fabric or garment cleaning: cleaning, drying, and finishing. The cleaning process starts with the sorting of garments into similar fabric weights, colours, and finishes. Garments are examined for stains and spotting agents are applied to remove them. Garments are then manually loaded into the cleaning machine and are washed by immersion and spin-agitation in a solution of tetrachloroethylene and detergents. The solvent is extracted by first draining, and then spinning the clothes. Cleaners occasionally add second washing and extraction steps for better cleaning. Garments are then dried through a combination of aeration, heat and tumbling in the machine. Finally, garments are manually removed from the machine, examined for spots, and then pressed.

One important characteristic of the drycleaning industry is the machinery used, as the functions of the equipment affect the environmental releases, human and environmental exposures and economic impact. Most drycleaning machines comprise the following parts: rotating cylinders or drums for washing, extracting, and drying; solvent storage tanks; a still; filters; a lint and a button trap; water separator(s); and solvent vapour recovery devices, and/or other devices.

Drycleaning machines have been constantly evolving since the 1960s. There are two main types of cleaning machines: transfer and dry-to-dry. Transfer machines (also called ‘first generation’) have separate units for cleaning and drying, so workers need to transfer garments which have been immersed in tetrachloroethylene from the washer to the dryer. Dry-to-dry machines wash, extract and dry clothes in the same cylinder in a single machine, so garments enter and exit the machine dry. Dry-to-dry machines may be called ‘second’, ‘third’, ‘fourth’ and subsequent generations depending on the design of their internal vapour recovery system. The development of drycleaning machines and their major features are shown in Table 3.

Table 3 - Major features of drycleaning machines (after US EPA, 1998)

Drycleaning Machine	Major Features
First generation	Transfer machines
Second generation	Dry-to-dry machine with conventional condensers
Third generation	Dry-to-dry machines with refrigerated condensers and do not vent aeration air (so called ‘closed-loop’)
Fourth generation	Third generation with an integrated carbon adsorber
Fifth generation	Fourth generation with an interlocking system

Vapour recovery of tetrachloroethylene in the drycleaning machine occurs during the drying cycle when heated air is forced into the cylinder containing the wet clothes and tetrachloroethylene vaporises into air. The heated air containing tetrachloroethylene passes through a lint bag and enters a condenser. The condenser cools the air and condenses some of the tetrachloroethylene which is recovered. The air from the condenser is repeatedly reheated and cycled back to the cylinder until there is very little tetrachloroethylene in the heated air stream.

Conventional condensers are usually cooled using water which may be circulated or once-through. Circulated water passes through a cooling circuit such as a cooling tower or a water chiller. Some conventional condensers may use air for cooling rather than water.

Refrigerated condensers operate at lower temperatures than conventional condensers and more tetrachloroethylene is recovered from the air. Machines with refrigerated condensers also have a cool-down cycle following the drying cycle during which more tetrachloroethylene can be recovered.

Third generation machines were designed in the early 1980’s and are closed loop machines that do not vent tetrachloroethylene to the atmosphere but recycle it continuously throughout the drycleaning cycle. Therefore the only exchange with the atmosphere occurs during loading and unloading of clothes.

Subsequent machine generations have been designed by adding additional equipment to reduce emissions at the end of the drying cycle. Examples are the use of an integrated carbon adsorber which is activated at the end of the cool-down step to further reduce the tetrachloroethylene concentration in the rotating cylinder by absorbing tetrachloroethylene to the carbon, and interlocking systems which assures that the tetrachloroethylene concentration is below approximately 300 ppm before the loading door can be opened.

According to the DIA, the majority of machines used in Australia are third and fourth generation machines, with only a few second generation machines still in operation. Some of the newly developed fifth generation machines are currently being commissioned. First generation machines have never been used in Australia. This information is consistent with the types of machines observed on site visits.

At the premises visited, loading of tetrachloroethylene into the machine varied from site to site. At some sites tetrachloroethylene is delivered by truck and directly pumped into the machine which has two or three solvent tanks. The capacity of the tanks varies with different machines. At some sites tetrachloroethylene is purchased in 10L containers and manually poured into the machine from the front. At these sites the 10L containers were stored on spill trays in well-ventilated places and the empty 10L containers are collected for re-use by the distributors of the chemical. At one site visited, tetrachloroethylene was delivered by truck but was pumped into a drum with a tap on it. The operator then filled 10L containers from the drum and manually poured this into the machine. The frequency of loading and the amount of tetrachloroethylene used at each site varies depending on the type of machine and enterprise size. The annual usage of tetrachloroethylene per site ranges from 100L to 1000L a year.

During 1999 - 2000, the NSW EPA visited 28 drycleaning premises using tetrachloroethylene. Some problems identified during these site visits included:

- No spill tray;
- Solvent not stored in bunded area;
- Machine not equipped with wastewater purification;
- Presence of tetrachloroethylene odour;
- Material safety data sheet not available; and
- Limited understanding of legislative requirements.

Information on the extent of these problems across the sites visited was not provided (NSW EPA, 2001 personal communication).

One cleaning cycle usually takes about 20 to 40 minutes. Possible leaks around the machine can be checked with a halogen leak detector either by a machine operator, or, at the request of the owner, by a representative of the company selling tetrachloroethylene. The latter seems the more common method used. The halogen leak detector does not measure actual air levels of tetrachloroethylene, rather it detects the presence of halogens in the atmosphere. Some premises undertake this regularly or whenever there is a suspicion of tetrachloroethylene leakage. Some parts of the machine such as the lint filter, still and button traps are cleaned manually on a regular basis. The frequency ranges from once every load to once a week depending on the types of machine and fabric cleaned. The still wastes which contain small amounts of tetrachloroethylene are transferred to a sealed container. In some advanced machines the still is emptied and cleaned automatically in a sealed set up. The wastes are then removed by a registered waste management company.

General ventilation, air conditioning and/or industrial fans were observed at most sites visited. Exhaust ventilation was seen at one commercial drycleaning site.

6.4.2 Coal flotation test

An estimated 26 tonnes of tetrachloroethylene per year is used in the coal industry. This estimation is based on usage of approximately 4 drums weighing 330 kg per laboratory, per year in 20 laboratories Australia wide. NICNAS visited two laboratories.

When coal is mined it is mixed with rock and other debris. The rock and debris is separated out at the coal washery using a technique based on density. The washery separation equipment is set to an appropriate specific gravity to ensure maximum coal recovery or to meet a customer's specification. Tetrachloroethylene is not used in the washery but is used in a test to determine the specific gravity of the various fractions of a sample provided by the mine. The test is also used as an audit check on waste removed from a washery in order to check that the density of the washery medium is set for maximum coal recovery at the mine and that no usable coal is being sent to waste.

Tetrachloroethylene (specific gravity 1.63); white spirit (specific gravity 0.83) and tetrabromoethane (specific gravity 2.85) are mixed to obtain stock solutions of differing densities for the test. Tetrachloroethylene is used for all solutions. To obtain specific gravities of less than 1.60 tetrachloroethylene is mixed with white spirit. For specific gravities greater than 1.60 tetrachloroethylene is mixed with tetrabromoethane. Although a number of alternatives to tetrachloroethylene have been tested by the laboratories none have proved successful.

Stock solutions are made up covering 12 different densities. The test area consists of large metal basins in which containers (25 and 64 and 200 litre) are placed. The containers are filled with solution to about 75% of capacity and have lids fitted to them.

The process begins with the sample from the mine being crushed to a specific size and weighed. The operator first checks the specific gravity of each container with a hydrometer. The density of each container is adjusted, if required, by adding one of the above chemicals. During hot weather adjustment is required more often because of evaporation.

The crushed sample is then placed into a wire basket and lowered either by hand or a manually operated winch into a solution with the lowest density. The sample separates out with some floating on top and some sinking either to the bottom of the basket or to an intermediate point depending on the density of the fractions in the sample. The fraction floating on top is scooped out manually using a strainer and washed in white spirit. It is then placed on a tray.

The basket is removed from the first container, allowed to drain, and then placed into the solution with the next lowest density, and the process repeated until the sample has been through as many solutions as are necessary to fully characterise the sample.

At one site the various fractions are dried in an oven maintained at 40^0C. This temperature is maintained so as to avoid thermal decomposition of tetrachloroethylene, which leads to the formation of phosgene. The dried fractions are weighed and sent to another section of the laboratory for further assay. At the other site the fractions are placed on a concrete slab outside the building and air dried. The filter paper and filtered particles are disposed of in the normal factory waste.

The test involves one operator and can be conducted occasionally or continuously over several days.

The different solutions are used repeatedly until they have become contaminated (generally by particles smaller than the mesh size of the basket). They are then passed through filter paper and the solutions are re-used.

6.4.3 Textile scouring

When yarn or material is manufactured it is contaminated with naturally occurring minerals, dirts and oils that must be removed prior to dying. Lubricants from the manufacturing process are also present and must be removed. The cleaning process is called “scouring”.

In a process similar to drycleaning, lycra and lycra blend fibres are scoured using tetrachloroethylene in a totally enclosed system. Other fibre types are amenable to aqueous scouring so the chemical is not used on those.

At one company, the chemical is either delivered in 250 litre drums or by bulk tanker. In the latter case it is pumped directly to a storage tank. In the former a spear is inserted into the drum and the opening around the spear is sealed. Tetrachloroethylene is then pumped into the machinery that cleans the fibres in the chemical. Once cleaned the fibres pass to a heated oven where the remaining chemical is vapourised. Any fumes generated in the process are recovered through a scrubber system. At the end of the cycle dried fibre is delivered from the machinery.

This company uses 24 tonnes of tetrachloroethylene per year in this manner. About 4 tonnes of tetrachloroethylene per year is lost in the sludge left after scouring. This sludge is removed, and disposed of by a licensed contractor. It is estimated around 15 tonnes of the chemical is lost to the atmosphere per year.

6.4.4 Film cleaning

After cinematographic film has been exposed it is developed and printed at a film production site for use in cinemas. Tetrachloroethylene is used to clean dirt, grease and minor scratches from the print and the negative films prior to printing. Tetrachloroethylene has been used for film cleaning for several years and is a replacement for 1,1,1-trichloroethylene. NICNAS visited one film production unit. Tetrachloroethylene is stored in a drum in an attached building, separate from where the chemical is used. The drum is opened and a spear manually inserted through the open bung hole. There is no seal provided around the spear. The spear is connected to a pump and system of pipes to transfer the chemical to the areas of the complex where it is used.

The cleaning of negative and print film is performed in separate air-conditioned areas. Cleaning is carried out in enclosed machines with both chemical and any vapours being recovered and recycled.

To clean negatives, the film is manually placed in the machine, which is then closed and tetrachloroethylene is pumped into a reservoir in the machine. The film is then wound from the supply reel to a take-up reel passing through the chemical bath. This is done at room temperature and is automatic once the film is loaded. After completion of the cleaning cycle, the machinery is opened and the film spool removed.

Cleaning of print film is undertaken using a similar system to cleaning negative film. In this case, the process is undertaken in a dark room as the film is printed using a wet process immediately after the print film passes through the bath of tetrachloroethylene.

The site visited used up to 3 tonnes of the chemical a year. About 4 other similar laboratories exist in Australia, hence an annual usage of 15 tonnes was estimated. Tetrachloroethylene is recycled in this process and any waste is removed by licensed contractors.

6.4.5 Vapour degreasing of metal

Only one user of tetrachloroethylene for vapour degreasing was identified. Annual use of the chemical is approximately 0.5 tonnes.

Australian Standard AS 2661 – Vapour Degreasing Plant – Design, Installation and Operation – Safety Requirements (Standards Australia, 1983) provides guidance on the safe design and operation of vapour degreasers. It is unknown whether the degreasing unit meets the Australian Standard as the company uses a degreaser they had built themselves.

The degreasing unit consists of a metal “vat” with a lid. It is not sealed, however, or used in an isolated area. Tetrachloroethylene is manually poured into the unit after decanting from a 200 litre steel drum. It was reported that there is significant evaporation of the chemical on hot days.

Parts to be cleaned are placed into the degreaser and then covered with the lid. Steam is piped through the unit in order to heat the tetrachloroethylene and the operator leaves the area. After a time the operator returns and manually removes the cleaned parts, which are then dipped into a separate bath of liquid tetrachloroethylene to ensure, they are fully cleaned.

6.4.6 Catalytic reforming in petrol production

At petroleum refineries crude oil is separated into a number of fractions by atmospheric and vacuum distillation. The naptha fraction contains many cyclic saturated hydrocarbons and is used to produce aromatics by catalytic reforming in a process using heat, pressure and a platinum catalyst. Tetrachloroethylene is used as a source of chlorine in the reaction and is added in small amounts in the reforming process as necessary. Estimated annual use of tetrachloroethylene by one refinery was 1.6 tonnes.

There are eight petrol refineries in Australia and all use the reforming process though tetrachloroethylene is not necessarily used by all refineries. The use of the chemical in this process is totally enclosed.

6.4.7 Maskant

One company in the aerospace industry used the chemical as a solvent in a maskant rubber compound in volumes of 25 tonnes in 1999. Chemical maskant formulations are used to protect surfaces from chemical etchants. In this particular company certain metallic parts which must be "machined" to exacting tolerances are chemically "milled" rather than mechanically. Tetrachloroethylene is used to thin the rubber maskant compound into which the part to be "milled" is dipped. The use is in a fully enclosed automated system with any fumes being passed through a scrubber, with minimal operator exposure to the chemical. At an intermediate stage in the process and at the end the maskant is stripped from the part and the waste disposed of by licensed contractors.

6.4.8 Laboratory solvent

Less than 16 kg per year of solvent grade chemical in one litre metal cans are imported and are used as a solvent in laboratory testing associated with oil exploration. Tetrachloroethylene is used to carry hydrocarbon liquid in a gel permeation chromatograph. The laboratory is located offshore onboard a ship, with the assay system being partly enclosed.

6.4.9 Analytical reagent

Approximately 450 kg of analytical grade tetrachloroethylene for laboratory analysis was imported in 1999 in glass bottles and occasionally 25 litre drums. This is up from 190 kg in 1995. The chemical is sold to laboratories without repackaging.

6.5 Formulation and use of products containing tetrachloroethylene

6.5.1 Aerosol car care products

Approximately 105 tonnes of tetrachloroethylene per year are used to formulate aerosol car care products. This amount varies according to demand. Three product lines are formulated, a tyre shine, a brake cleaner and a lithium based spray grease. In these formulations tetrachloroethylene has replaced 1,1,1-trichloroethylene. These products are used by the public and in workplaces by spraying onto the car parts. NICNAS visited one manufacturer of these products.

Brake Cleaner – This product consists of tetrachloroethylene with the remainder being the aerosol propellant gas. "Pure" chemical is therefore sprayed on the brake parts by the user. During product manufacture tetrachloroethylene is drawn from a drum to the filling and packaging line through a hose via a sealed connection. The drum is placed on its side and the chemical allowed to drain into the packaging line. This line is to be replaced by an automatic line shortly, but currently it is operated by three workers who rotate the duties through an 8 hour shift.

The first operator takes a spray can and places it under a filler nozzle. A pump is then operated by the worker and a metered amount of chemical is injected into the can. This person then places the valve assembly into the can and passes it to another worker. The second worker places the can into a machine, which fits the valve assembly and injects propellant gas into the can. This operation is done behind a closed shutter in case the can explodes when being gassed. The filled cans are passed on a conveyor to a third worker who packs the cans into boxes.

Tyre Shine and Spray Grease – These are products in which tetrachloroethylene is mixed with other ingredients. In these products tetrachloroethylene is used purely as a solvent for the other constituents. The products are mixed in large vats in a formulation area.

The drums of tetrachloroethylene are bought from the store by forklift and placed in the mixing area. The bung hole is opened and a spear connected to a pump is inserted into the drum. The spear does not form a seal. All the constituents of the product are added to the vat, which has a lid, and a mechanical stirrer inserted through a hole in the vat lid. The stirrer does not form a seal around the hole. Once mixed the product is piped to automatic filler lines with valve sealing and gassing of the can. The filler lines are located in a separate small building adjacent to the formulation area.

6.5.2 Electric motor and electrical equipment cleaners

Five electrical cleaning products formulated locally using tetrachloroethylene were identified.

One product contains a mixture of tetrachloroethylene (20%-30%), trichloroethylene (20%-30%) and other hydrocarbons. It is supplied as a liquid in 25, 60 and 200 litre containers and is either sprayed or brushed onto the component or surface to be cleaned. It is claimed the product can be used without switching off the electric motor (DC motors however must be switched off according to the product label).

The other four products contain either 10-60%, 10-30% or 30-60% tetrachloroethylene and are sold to industry either as an aerosol or in 20 litre and 200 litre drums for application by spraying, brushing or dipping.

The formulation and packaging process of the products was described by the formulators as being carried out on fully and partly enclosed lines respectively. Extractor heads over the lines are used to draw vapours through a scrubber system.

6.5.3 Cleaning of flexographic printing plates

The flexographic printing plate cleaning products are formulated by mixing tetrachloroethylene and n-butanol. Tetrachloroethylene used in the formulation is either from imported chemicals or, recovered from used cleaning product. The product consists of 60-75% tetrachloroethylene and about 25% n-butanol. The formulation and recycling processes are fully enclosed.

Flexographic printing is an industrial process whereby a flexible type film is employed with a reactive monomer coating. The image to be printed is overlaid on the film, which is then exposed to ultra violet light, converting the exposed parts to a polymer. The plate is then washed in the cleaning solution containing tetrachloroethylene, which dissolves the unpolymerised coating and leaves a slightly raised image of what is to be printed. The entire process is performed in automated, enclosed machinery. The finished plate is used in printing that requires a small number of different colours (for example cartons used as packaging for beer bottles and cans) and for printing of plastic packaging.

The used cleaner is either disposed of or collected and recycled. When recycled, the used film cleaning solution is processed under heat and in a vacuum to precipitate the non-polymerised reactive film coating leaving an uncontaminated solution, which is then reblended to the correct proportions of tetrachloroethylene plus the other constituents and re-sold.

6.5.4 Textile scouring

Scouring, as described above (section 6.4.3), is also undertaken using formulated products containing tetrachloroethylene and other constituents such as surfactants.

Two companies manufacturing a total of three textile scouring products were identified. These products contained tetrachloroethylene in varying amounts from around 20% to up to 60%, and are used by the textile industry. The formulation processes were described as fully enclosed. One manufacturer reports that its products are made in very low volumes of about 400 litres per year.

The formulated products are used as a last resort for removing spotting where pure tetrachloroethylene has not removed the stains. The concentration of tetrachloroethylene however is low. As with the pure chemical use in textiles, the products are used almost exclusively on lycra and lycra blend fibres.

In these processes, the product containing tetrachloroethylene in the proportion of 30-60% is added to an open water bath in concentrations of about 1 ml/litre. The volume of solution in the bath varies. The bath is steam heated to around 80^0C and the yarn or material passed through the bath to remove the impurities.

In the fibre dying process the scouring product referred to above, is placed in a slightly acid bath with other additives including the dyestuff and heated to up to 130^0C for up to 45 minutes (longer timed processes are usually heated to lower temperatures), depending on the fibre type being dyed.

One textile company uses pre-formulated scourers diluted in a total of 2ML of water over a day's production. The amount of tetrachloroethylene used totals about 270 mL/day. Concentrations in individual baths however vary. This company intends to phase out the use of these products based on environmental concerns.

These products do not appear to be widely used in the textile industry in Australia.

6.5.5 Fabric care products

Fabric care products are used in the drycleaning industry to clean curtains and to remove odours from specialised drycleaning plants. Three products are locally formulated by Orica who did not provide details of the formulation process. They contain 1-9% tetrachloroethylene in one product and 30-60% tetrachloroethylene in the other two products. These products are specially formulated for use in a particular type of curtain cleaning machine, of which there are very few in Australia. The cleaning products are added to the drum of the machine with corn husks that have been soaked in tetrachloroethylene and the curtains are put through the cleaning cycle. Usage of tetrachloroethylene in these products is approximately 80 kg per annum.

6.6 Use of imported products containing tetrachloroethylene

6.6.1 Electric motor cleaner

This product is only imported in small quantities, and is available in aerosol cans and 20 litre drums. In recent years only the aerosol form has been imported. Total imports in 1999 accounted for 11 kg of tetrachloroethylene, according to responses to a NICNAS survey. The imported product is used in the same way as the locally produced electric motor cleaner discussed above.

Composition of the products is 95-99% tetrachloroethylene for the aerosol and 100% tetrachloroethylene for 20 litre drums. Users are mainly in industry but consumers may also use the product.

6.6.2 Carpet stain remover

This product contains approximately 12% tetrachloroethylene. Import volume is low with less than 0.5 tonnes imported in 1999. The product is sold to the general public and used by spraying onto stains on carpets, then rinsing with water.

7. Exposure

7.1 Occupational exposure

The major routes of exposure in an occupational setting are by inhalation of fumes and by skin contact with the chemical. Monitoring data of exposure levels is only available for the drycleaning industry and in very limited form for the coal flotation tests.

7.1.1 Ship to shore transfer and distribution

Transfer from the ship's hull to storage is automated via a permanent wharf pipeline.

Trucks are top loaded via a metered pipeline with emission control measures in place from the dedicated storage tank. An automatic carbon absorption vapour extraction system draws air from around hose connections at tanker and drum filling stations, and openings on bulk storage tanks. Workers are required to wear safety glasses, hard hat, safety boots, long sleeve clothing and viton gloves as a minimum plus an organic vapour respirator if risk of inhalation exists. Exposure by inhalation is not expected during normal operation.

There is the potential for short-term exposure to tanker drivers when coupling and uncoupling piping, during the filling of 10 litre containers and when delivering bulk supplies to customers. Drivers wear protective clothing including boots, viton gloves, safety goggles and carry respirators for use when necessary.

7.1.2 Drycleaning

During drycleaning, workers are likely to be exposed to tetrachloroethylene by inhalation and skin contact during manual charging of tetrachloroethylene into the machine, loading and unloading drycleaning machines, steam pressing that eliminates any residue of the solvent which may remain in a garment at the end of the processes, and cleaning and maintenance of machine parts. However, inhalation is the predominant route of occupational exposure as tetrachloroethylene volatilises readily and is well absorbed from the lungs.

According to the 'Profile of the Australian Drycleaning Industry' provided by DIA (DIA, 2000), there are currently about 1200 on-site drycleaning enterprises employing approximately 9000 people in Australia. Changes in the number of drycleaning sites in Australia from 1979/80 to 1997, are shown in table 4.

Table 4 - Number of drycleaning sites by employment across the period 1979/80 to 1997 in Australia.

Enterprise Size	1979-80		1986-87		1997	
	#	%	#	%	#	%
0-4 persons	1769	69.72	1087	68.75	655	53.65

5-9 persons	530	20.86	286	18.08	297	24.36
10-19 persons	138	5.44	120	7.59	164	13.45
20-49 persons	68	2.68	63	3.99	82	6.72
50-99 persons	18	0.71	13	0.83	11	0.90
100+ persons	15	0.59	12	0.76	10	0.82
Total	**2538**	**100**	**1581**	**100**	**1219**	**100**

number of sites

Over the last two decades, the total number of drycleaning sites in Australia has been decreasing, particularly the number of small size enterprises. Small enterprises, as a percentage of total drycleaning enterprises, have significantly decreased from about 70% to 54%, while the percentage of medium size drycleaning companies has increased slightly. According to DIA, the apparent decline in numbers of small size enterprises is due to a combination of factors which include failure to replace obsolete equipment, increasing managerial expertise required, increasing occupational health and safety and environmental regulatory compliance requirements, shortage of skilled staff and extension of trading hours.

Currently, most drycleaning enterprises, especially retail sites, run 7 days a week and 12 hours per day. The extent of potential exposure to tetrachloroethylene varies depending on a number of factors including the type of machines used, work tasks, amount of clothes cleaned daily, job categories, and workplace exposure controls.

The type of drycleaning machine significantly impacts on control of exposure to tetrachloroethylene. There is no detailed information available on the age of drycleaning machines currently used in Australia. However, DIA states that the majority of machines are third and fourth generation machines. Some of the newly developed fifth generation machines are currently being commissioned. First generation machines have never been used in Australia and only a few second generation machines are still in operation. Inhalation exposure of the workers is expected to be continuous and higher in workplaces using second generation machines, which vent tetrachloroethylene vapour to the atmosphere, than workplaces using non-venting type of machines. Workers operating newer generation machines, which have additional equipment to reduce emission of tetrachloroethylene, would have less exposure.

Workers are expected to have the greatest potential to exposure when cleaning and maintenance tasks are performed, but these activities usually occur only once a day for a short period of time. Loading and unloading the machine may have higher level of exposure to tetrachloroethylene as these procedures usually occur several times a day depending on the amount of clothes cleaned.

Drycleaning workers may be categorised into various job titles such as operator, clerk and presser based on worker activities. Potential exposure is expected to be higher in machine operators, but it may vary if workers have rotating responsibilities and overlapping activities.

No personal protective equipment is used during operation of drycleaning machines. A mask and gloves are worn, at some sites visited, during manual cleaning of machine parts.

Australian air monitoring data

Orica Australia Pty Limited, a major supplier of tetrachloroethylene to the drycleaning industry, has conducted an air monitoring program for its customers across all States and Territories of Australia since the late 1980s. A report of the air monitoring data collected during 1989 to 1998 was provided (Orica, 2000).

A total number of 537 personal samples, representative of the workers' breathing zone for tetrachloroethylene vapour, were obtained from 196 plants across all States and Territories. The majority of samples were collected in Victoria (268), with the least in the Northern Territory (6). The 8-hour time-weighted average (TWA) levels of tetrachloroethylene in air were measured using passive dosimeters. Samples were collected using 3M organic vapour monitoring badges. Approximately half of the 196 plants were sampled once only. Where high exposures were measured, follow-up visits and samples were undertaken. Several plants were sampled a number of times. The samples were analysed by gas chromatography (GC) technique with flame ionisation detection. The types, number of drycleaning machines used at the sites and workers' job titles are not specified.

The results show that the mean and geometric mean exposures are 10.3 and 4.7 ppm respectively. Thirteen (3%) of the 537 samples were above 50 ppm and 90% of exposures were less than 25 ppm.

Overseas air monitoring data

There is a large amount of overseas air monitoring data available measuring inhalation exposures to tetrachloroethylene for drycleaning workers. However, much of the data is either old or details such as the year and duration of measurement are unknown. Only recent data with sufficient details are discussed below.

A US EPA report (1998) summarises US monitoring data from four data sets: OSHA, published studies, the International Fabricare Institute and the National Institute of Occupational Safety and Health (NIOSH). In the US EPA report, the data was analysed to demonstrate variations in worker inhalation exposure due to factors such as machine types and controls, job titles, and number of machines per workplace. An obvious decreasing trend in tetrachloroethylene exposure levels over the past decade was found. Workers using transfer machines have higher potential exposure than workers using dry-to-dry machines. The dry-to-dry, closed loop, with integrated carbon adsorber machines (fourth/fifth generation) result in significantly lower worker exposures (about 1.6 ppm) than all other types. Generally operators had higher exposures than non-operators. It was also found that exposure levels increase as the number of machines used at the sites tested increases.

An organic vapour monitoring program, implemented by Dow Chemical Company in the US, was conducted during 1989 to 1995 (Dow, 1996). A total number of 581 samples were obtained and measured using dosimeters. The data were analysed according to whether the drycleaning process involved retail dry-to-dry or retail transfer operations. The samples included area and personal sampling, but it was claimed that the majority of the data related to personal 8-hour TWAs. The average exposure concentration was 25.9 ppm (range 0.1 – 239 ppm), in which average exposure levels were 17.8 ppm with dry-to-dry operations (339 samples) and 37.2 ppm with transfer operations (242 samples).

More recent data (1997-1999) provided by Dow Chemical Company in the US (Hickman, 2000) show that in a total of 914 samples, the percentage of 8-hour TWA personal samples less than 10 ppm are 58%, 70%, and 100% for second, third and fourth/fifth generation machines respectively. The average exposure (8-hour TWA) is approximately 37 ppm using first generation, 9 ppm with third generation and 5 ppm using fourth/fifth generation machines. The data indicate that emissions of tetrachloroethylene were significantly reduced when venting ceased, i.e. the introduction of third generation machines. Again when additional equipment such as an integrated carbon adsorber and an interlocking system were added (fourth/fifth generation machines), the level of tetrachloroethylene in air was further reduced.

Air monitoring data during 1982 to 1994 from Belgium, Finland, Germany, Italy, Switzerland and UK are summarised by the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC, 1999) and show that average levels of tetrachloroethylene in air were generally less than 30 ppm. Older data (before 1980) from the Netherlands and the UK show higher levels of up to 60 ppm and 100 ppm respectively.

Summary of occupational exposure

It is known that the majority of machines now in use in Australia are third and fourth generation machines with some fifth generation machines currently being installed. Australian air monitoring data from the 1990s indicate that the average exposure to tetrachloroethylene (8-hour TWA) was approximately 10 ppm. This is consistent with US exposure data for similar drycleaning machines. Based on recent US monitoring data, exposure levels to tetrachloroethylene should continue to be reduced in the future by replacement of older drycleaning machines with newer generation machines. In addition, drycleaning machines will continue to be developed and it is likely that this will lead to further small reductions in tetrachloroethylene emissions.

7.1.3 Coal flotation test

Two sites were observed performing the test, either in a dedicated section of a main factory shed or in a separate shed. Both sites were equipped with local exhaust ventilation.

At these facilities workers conducting the test wore full-face or half-face respirators, safety glasses and PVC gloves. Protective aprons were also used at one facility. Workers stated that PVC gloves had a short life expectancy with tetrachloroethylene and had to be replaced regularly.

In 1995, the Workcover Authority of New South Wales undertook a workplace assessment, including limited air monitoring of the flotation test in one laboratory. An edited version of the data obtained is presented in Table 5 and is reproduced with the permission of the Workcover Authority.

Personal sampling (representative of the workers breathing zone) for exposure to solvents was carried out on operators of the float/sink bath. Static sampling was also undertaken. During the sampling the operators wore a half-face respirator, PVC gloves, apron and a face shield. At the site monitored local exhaust ventilation was utilised during the process.

The sampling was carried out in accordance with Australian Standard AS2986 - 1987 *Workplace Atmospheres - Organic Vapours - Sampling by Solid Adsorption Techniques* (Standards Australia, 1987). Samples were collected using activated charcoal tubes at a flow rate of 100ml/min and analysed using gas chromatography.

The limited monitoring data indicates exposures can go above the occupational exposure limit. This flotation test is an open process performed with regularity. Worker exposure therefore could be significant.

Table 5 - Personal and static atmospheric levels of tetrachloroethylene experienced by operators in the coal flotation test

Operator	Tube Type	Tetrachloroethylene (ppm)
Personal	Charcoal (day 1)	14
Static	Charcoal (day 2)	1
Personal	Charcoal (day 2)	57

7.1.4 Film cleaning

This process was enclosed with tetrachloroethylene mechanically pumped into the machines through a system of pipes

The only potential for exposure to tetrachloroethylene observed at the film cleaning site visited would be from vapours when the drum is opened and whilst the drum has the spear inserted. No odour was noted in the storage area at the site visited. Exposure of workers to tetrachloroethylene is likely to be low.

7.1.5 Vapour degreasing of metal

Use of tetrachloroethylene as a vapour degreaser appears to be limited with only one site identified as using the chemical.

Potential for operator exposure to tetrachloroethylene could not be determined on the information available, but could be expected to occur when the lid of the degreasing unit is lifted to place in or take out parts being cleaned, when chemical is added to the unit and when cleaned parts are rinsed in tetrachloroethylene following degreasing. It is unknown whether any ventilation is provided around the degreaser or whether any safety gear is worn by the workers.

7.1.6 Catalytic reforming in petrol production

This process was described as fully enclosed. Injection of tetrachloroethylene into the reaction vessel is automated. Exposure is therefore likely to be low.

7.1.7 Maskant

Because it is enclosed there is minimal operator exposure to tetrachloroethylene in the normal course of the process. There is a permanent bulk tank for tetrachloroethylene, which is filled from a road tanker. To begin the process an operator opens a valve from a control panel, which allows tetrachloroethylene to flow by gravity feed into a mixing vat containing the maskant compound. The mixing vat is a closed system. The thinned maskant goes from the mixing vat to an enclosed dipping section where the part to be etched is dipped into the solution then allowed to dry. Once the maskant has dried on the part to be etched the part is removed from the dipping section. Tetrachloroethylene evaporates during this drying stage. A template is then placed over the part and an operator cuts sections of the maskant from the part following the template, thereby exposing the sections of the part that are to be etched. The waste maskant is put into hazardous waste drums for removal by a licensed contractor. The part is then returned to the line and put into an etching bath. Once etched, the part is removed and the remaining maskant stripped by hand as before, with the waste again treated as hazardous. Any fumes generated in the process pass through a scrubber system. If an operator needs to enter an area where exposure to tetrachloroethylene could occur, then personal protective equipment is worn.

7.1.8 Laboratory use

The potential for exposure in these areas was not determined and would depend on analytical technique and the type of analysis being performed.

In formulation of product, personnel are potentially exposed to tetrachloroethylene during collection of product samples from production lines for quality control purposes and analysis of those samples.

7.1.9 Aerosol car care products

Formulation

On site formulation was naturally ventilated and takes place in enclosed vats. Transfer of tetrachloroethylene into the vat, and of product from the vat, occurs via pipes.

Filling

Worker exposure to tetrachloroethylene vapour could occur at the filling stage and at the time just before the valve assembly is sealed in place. Additionally an unsealed can could be knocked over thus exposing workers to spills. Protective gloves were not worn by workers on the basis that gloves made the cans difficult to handle and manipulate.

It was noted that safety glasses were worn. The employer intends to install an automatic line in the near future, which once in place is likely to eliminate these potential problems. The automatic line (already used for another product) incorporates a separate building where the gassing occurs. No employees work in this separate building with the automatic filling line. Worker exposure to tetrachloroethylene for the formulated products would therefore be limited to the mixing area only.

Occupational use

During use the products are sprayed so a potential for worker exposure exists. However, it is anticipated that the products would be used intermittently on a needs basis and for short periods of time.

7.1.10 Electric motor cleaner

The manufacture of this product is described as being fully enclosed in the formulation stage and partly enclosed at packaging. In use the product is sprayed either from aerosol cans or used in spraying equipment, which is filled from chemical supplied in drums. Operator exposure could potentially be significant if motors are being cleaned regularly and/or are located in confined areas.

7.1.11 Flexographic film cleaner

Formulation

Formulation occurs at one facility. The product is made in an enclosed system either by recycling used cleaner and adding fresh ingredients to bring the mix to the correct proportions or made entirely from fresh ingredients.

For recycled film cleaner, the drums of used product are opened and a spear inserted to pump the product to the recovery vessels. Other drums of unused chemicals are bought to the mixing area, opened and a spear inserted to pump unused chemical to the mixing vat. The spears do not seal around the drum openings.

For mixing product from unused chemicals the process is the same except that product is not pumped to the mixing vat from recovery vessels. Worker exposure in both processes is limited to opening the drums of raw chemical or used product and opening the recovery vessels to remove precipitated polymer at the end of the recovery cycle. Exposure therefore is likely to be low.

Occupational use

The flexographic printing plate manufacturing process is undertaken in large enclosed machines so exposure to the chemical in using the products is likely to be low.

7.1.12 Textile scouring

Only three workplaces were identified as using tetrachloroethylene containing pre-formulated products for textile scouring. In these workplaces, worker exposure is likely to be low because of the low concentrations of tetrachloroethylene in the bath and intermittent use.

Use of the pure chemical in scouring results in low worker exposure because of the enclosed nature of the process.

7.1.13 Fabric care products

The use of these products is limited to specific types of machines of which there are reportedly few in Australia and which are used for curtain cleaning only. No further information was available on the design and use of the machines.

7.2 Environmental exposure

7.2.1 Environmental release

Due to the volatility and predominant end-use pattern of tetrachloroethylene, the majority of the chemical used is expected to partition to the atmosphere with only minor amounts to water.

As a worst case, it can be assumed that all tetrachloroethylene imported into Australia in any given year is released to the environment.

Release to air:

Drycleaning

The primary drycleaning emissions of solvents are to air through both fugitive and direct emissions at the end of the cycle when the machine door is opened during loading and unloading operations. Other emissions may occur through poorly fitted or perished gaskets and seals fitted on filters and other integral parts of the machine that are used to filter and distil the dirty solvent.

Other industries

Virtually 100% of tetrachloroethylene used in aerosol car care products, electric motor and equipment cleansers, fabric care products and carpet stain removers may be expected to be released to air.

Other industries described in section 6 would be expected to have releases to air, but this will be limited by the control technologies in place and in the case of use in catalytic reforming in petrol production, the level of reaction of the tetrachloroethylene.

Release to water:

Drycleaning

Drycleaning produces a certain amount of wastewater that generally contains tetrachloroethylene at around 150 ppm (0.015%). The amount of tetrachloroethylene in the wastewater can be further minimised by using treatment such as carbon absorption. The amount of wastewater depends on the generation of equipment used. Wastewater containing tetrachloroethylene is classified as a hazardous waste by most State and Territory environment agencies and by local water authorities. Melbourne Water, for example, has a ceiling limit of 1 ppm for tetrachloroethylene and prohibits the emission of drycleaning wastewater to sewer.

Wastewater that does not meet local limits must be transferred to a licensed hazardous waste hauler for handling or treatment or disposal as hazardous waste.

Other industries

Where tetrachloroethylene is used in laboratories, for example in the coal industry or as a general solvent, some inadvertent release to water must be assumed. However, most of the excess tetrachloroethylene would be expected to be disposed of with the various laboratories liquid waste.

Significant release to water may result in the vapour degreasing and textile scouring industries. These industries use tetrachloroethylene in vats that are often open and may produce spillage. Improper disposal to sewer of spent vat liquid also cannot be discounted.

Point source releases:

Five reporting facilities provided information to the National Pollutant Inventory (NPI) for the 1998-99 year. The two major tetrachloroethylene emitters each reported release of 18 tonnes over the year to air, with releases estimated using emission factors. While not as accurate as direct measurement, this is considered acceptable for reporting purposes. Reporting to the NPI over this period was not compulsory, so it is expected the list of reporting facilities is not exhaustive. However, for the purposes of this preliminary assessment, these individual releases may be used as a guide.

One of the main emitters of tetrachloroethylene was in the printing industry with major operations being the manufacturing and printing of flexible plastic packaging material. The other was in the drycleaning industry with major operations being industrial laundryprocesses, (see Table 6).

Regional releases:

Based on NPI data, releases occur primarily through evaporation from the drycleaning industry. The following data were reported to the NPI during 1998-99. This is not expected to be comprehensive as reporting was not compulsory during this year. However, the information provides a good indication of the major release sources. Information has been condensed from figures received for the Adelaide, Hobart, Kalgoorlie, Perth, Port Phillip Region, SE Queensland, and Sydney Newcastle Wollongong Airsheds.

Table 6 - Estimated tetrachloroethylene releases to air (Environment Australia, 2000)

Activity	Annual Release (tonnes)[1]
Drycleaning activities	1323
Domestic/commercial solvents/aerosols[2]	109
Printing (reported for Port Phillip airshed only)	18
Landfill (reported for Port Phillip airshed only)	1.8
Fuel combustion – sub reporting threshold facilities[3]	<0.1

1) Releases are not exhaustive. They are a guide only as per data reported in the NPI. 2) Also includes the NPI category "Solvent Use – Sub-threshold facilities". 3) Includes the NPI category "Solid fuel burning (domestic)".

7.3 Environmental fate

Using phase volumes described by Connell and Hawker (1986), for the area in Canberra immediately surrounding and including Lake Burley Griffin, and assuming emissions of 36000 kg to this environment (twice the maximum single reported annual release from a point source), the Level 1 Fugacity Model predicts in excess of 99.9% tetrachloroethylene will partition to air at equilibrium with minor amounts to water and soil, and negligible amounts to sediment (Trent University, 1999).

7.3.1 Atmospheric fate

Where released to the atmosphere, tetrachloroethylene is expected to remain in the vapour phase (Howard, 1990) although it may be transported back to land and surface water in rain (ASDTR, 1997).

The primary removal mechanism from the atmosphere is through reaction with hydroxyl radicals, or chlorine atoms produced through photooxidation of tetrachloroethylene. Howard (1990) provides estimated photooxidation time scales ranging from an approximate half-life of 2 months to complete degradation in an hour. This is substantially faster than may be expected based on other references.

Reaction with other reactive trace species and direct photolysis are believed to make only a very minor contribution to the degradation of tetrachloroethylene. Physical removal of tetrachloroethylene from the troposphere by rainout or uptake by the oceans is negligible compared to chemical destruction (ECETOC, 1999).

Following procedures in the OECD Monograph 61, for tetrachloroethylene, an estimated rate constant of $0.18X10^{-12}$ cm^3/molecule/s is derived. This compares favourably to an experimental rate constant of $0.17X10^{-12}$ cm^3/molecule/s (OECD, 1993), and the experimental rate will be used to estimate an atmospheric half-life.

An accepted global average of hydroxyl radical concentration in the troposphere (day + night average) approximates $5X10^5/cm^3$ (Calamari, 1993). Applying this rate to the experimental rate constant, a half-life of around 136 days is derived. Half-lives reported in the literature range from 70 to 251 days (ASDTR, 1997), and 16 to 160 days (Howard et al, 1991) based on photooxidation half-life. With rate constants ranging from $1\text{-}2X10^{-13}$ cm^3/molecule/s, half-lives of 80.2 to 160.4 days are determined based on the globally accepted hydroxyl radical concentration (BUA, 1993). These indicate relative persistence in air.

The remainder of this discussion on atmospheric fate is paraphrased from the recently completed ECETOC assessment of tetrachloroethylene (ECETOC, 1999).

Laboratory studies carried out under simulated atmospheric conditions have enabled various reaction products to be identified with phosgene and trichloroacetyl chloride (TCAC) being the most common. Others include dichloroacetyl chloride, tetrachloroethylene epoxide, carbon oxides, formic acid, hydrogen chloride, chlorine, carbon tetrachloride and chloroform. It is noted that such studies should be interpreted with great caution and deviations from actual tropospheric conditions should be taken into account when postulating likely breakdown pathways in the real atmosphere.

Experiments carried out in the presence of chlorine scavengers demonstrate that TCAC is the product of the chlorine atom initiated oxidation pathway while hydroxyl radical degradation leads exclusively to one-carbon products, including phosgene.

Based on known rate constants for reaction of tetrachloroethylene with hydroxyl radicals and with chlorine (Cl) scavengers, and from available data on the tropospheric abundances of these two reactive species, it is concluded that the reaction of tetrachloroethylene with Cl represents approximately 13% of the overall atmospheric degradation of tetrachloroethylene. The TCAC thus formed will be partly photolysed (giving phosgene) and partly taken up by cloud, rain and ocean water and hydrolysed to trichloroacetic acid (TCA). The best estimate of the overall atmospheric yield of TCA from tetrachloroethylene is 5%, but there is considerable uncertainty and the value might conceivably range from 0.1-33%.

Simulated atmospheric degradation experiments carried out in 1975 concluded that carbon tetrachloride (CCl_4), an ozone-depleting substance, could be formed from tetrachloroethylene, with a yield of approximately 8%. More recent laboratory studies have confirmed the formation of this product, albeit in much lower yields. They have demonstrated that $CC1_4$ is a secondary and/or tertiary oxidation product, arising from the photolysis of TCAC or its hydrolysis product TCA, largely through heterogeneous reactions occurring on the walls of the reactor. $CC1_4$ is thus a minor product of the Cl atom initiated degradation pathway. From information provided by the laboratory studies and the estimate of the importance of the Cl atom pathway in the troposphere, it is concluded that the overall atmospheric yield of $CC1_4$ from tetrachloroethylene is unlikely to exceed 0.03%.

It is not meaningful to calculate an Ozone Depleting Potential for a substance with an atmospheric lifetime as short as that of tetrachloroethylene. Nevertheless, it is estimated that tetrachloroethylene contributes only around 1% of total current atmospheric chlorine loading and hence plays only a minor part in ozone depletion. Part of the small fraction of tetrachloroethylene that does reach the stratosphere (estimated at approximately 1.6% of ground-level emissions) is degraded to phosgene and returned to the troposphere where it is destroyed by hydrolysis. Thus not all the chlorine contained in the tetrachloroethylene entering the stratosphere is actually converted into ozone-depleting species. Furthermore, the tropospheric breakdown products arising from tetrachloroethylene (phosgene and possibly some TCAC) contribute considerably less to stratospheric chlorine loading than tetrachloroethylene itself.

The atmospheric photochemical reactivity of tetrachloroethylene is too low for it to make any significant contribution to local urban tropospheric ozone formation and the related "photochemical smog". Based on this, the US EPA has exempted this chemical from being regarded as a volatile organic compound (VOC).

7.3.2 Aquatic fate

Tetrachloroethylene is not expected to hydrolyse under normal environmental conditions.

Where released to water, the major removal process would be expected through volatilisation. The dimensionless Henry's Law Constant for tetrachloroethylene is 0.74. According to the scale of Mensink (1995), this indicates tetrachloroethylene will be highly volatile from water. The volatilisation half-life will depend on wind and mixing conditions and an aquatic half-life has been estimated to range from 3 hours to 14 days (Howard, 1990).

These rates are in contrast to other surface water half-lives provided by Howard et al, (1991) for surface water where half-lives ranged from 6 months to 1 year, and were based on scientific judgement using aerobic river die-away test data and saltwater grab sample data. Without having reviewed these data, these aquatic half-lives are considered to be high for a chemical compared with the vapour pressure and Henry's Law Constant of tetrachloroethylene.

Howard (1990) describes a mesocosm experiment conducted to simulate a bay during different seasons. Volatilisation was the major removal process during all seasons and seasonal differences can be explained by hydrodynamics. The measured half-lives were 25 days in spring, 11 days in winter and 14 days in summer.

Further studies are described in this same reference. Half-lives calculated from concentration reduction between sampling points on the Rhine River and a lake in the Rhine basin were 10 and 32 days respectively. In a seawater aquarium, an 8-day half-life was demonstrated to be predominantly through volatilisation. In a natural pond, tetrachloroethylene disappeared in 5 and 36 days at low (25 ppm) and high (250 ppm) dose levels respectively (Howard, 1990).

A further route of elimination is stated to be via anaerobic biodegradation by adapted microorganisms (BUA, 1993). It is reported that after 8 weeks under anaerobic, methanogenic conditions in batch culture, or after a 2-day retention period in closed, continuous flow-through columns, tetrachloroethylene was completely eliminated. This route is more relevant to removal of tetrachloroethylene from sewage treatment plants (STPs) than surface waters.

7.3.3 Terrestrial fate

Where tetrachloroethylene is released to soil it will evaporate relatively rapidly to the atmosphere due to its high vapour pressure and low adsorption to soil (Howard, 1990). Adsorption coefficients provided in the BUA report (1993), based on studies show a range in Kad from 0.9 in sand to 12.9 in acidic peat. For 18 selected soils a mean Kom, based on organic matter, of 138 L/kg was determined. The significance of these was investigated by determining the adsorption isotherms of 32 soils, and a resulting mean Kad of 102 resulted. Organic matter is strongly related to adsorption (BUA, 1993).

The author of the study considering the 32 soils claims that the process of adsorption in soil is shown to be highly reversible. The average Kdes for the same 32 soils was determined to be 158 (based on two desorption cycles) (BUA, 1993). This indicates the adsorption is not fully reversible, although it could be anticipated that a significant amount of the adsorbed tetrachloroethylene will subsequently desorb.

The above adsorption results are lower than those reported in Howard (1990) where Koc values of around 210 are provided. Additionally, a Koc of 238 was calculated based on the above reported Kom of 138 L/kg in a peaty soil. Based on the reported log Kow, a Koc of 1,685 is estimated suggesting tetrachloroethylene will be expected to exhibit low to medium mobility in soil and therefore may only leach slowly to ground water. However, this is only an estimated value, and experimentally derived values are more relevant to predict behaviour. Koc values of 177-350 and 0.5 ppm are reported in Verschueren (1996), although it is not clear whether these are theoretical or experimental results.

It may be expected that tetrachloroethylene could leach through sandy soil and therefore reach groundwater. In groundwater, tetrachloroethylene may persist for a number of years. Depending on conditions and following adaptation of the microorganisms (see anaerobic degradation below), gradual reductive dehalogenation to vinyl chloride can occur. So far, mineralisation of tetrachloroethylene in groundwater aquifers has not been demonstrated (BUA, 1993).

Calculated half-lives in a nonpolluted, anaerobic aquifer at varying organic carbon contents provided half-lives of 12 days, 34 days, 270 days and 12 years with organic carbon contents of 1, 0.1, 0.01 and 0.001% respectively (Verschueren, 1996).

7.4 Environmental biodegradation and bioaccumulation

7.4.1 Aerobic degradation

The following aerobic degradation discussion is based on results reported in the BUA report (1993). Aerobic degradation of tetrachloroethylene has not been suitably demonstrated and it is reasonable to assume tetrachloroethylene is non-biodegradable under aerobic conditions as supported by the following results.

Under aerobic conditions in a batch culture, no significant biodegradation of tetrachloroethylene at 8.8-74 ppb was observed. The substance was incubated in closed bottles for 25 weeks in the dark after being inoculated with bacteria from clarified effluent.

An experiment into biodegradation of tetrachloroethylene in a sample of Rhine water showed no detectable degradation following 42 days incubation in brown bottles on magnetic stirrers. Based on this, any significant aerobic biochemical degradation of tetrachloroethylene through surface waters was ruled out.

A long-term experiment on tetrachloroethylene degradation was conducted over 2 years in a continuous flow through system with tetrachloroethylene at around 10 ppb passed over a biofilm formed on a bed of glass beads. No degradation was determined.

Several results do show significant elimination of tetrachloroethylene from aerobic systems. However, this elimination cannot be attributed to biological degradation due to uncertainties in the process of elimination as reported in the following results.

The OECD ready biodegradability test showed 100% elimination. However, this was not attributed to biological degradation, rather to volatilisation of tetrachloroethylene from the test medium (recovery rate, 38%).

A 28-day static test in the dark in which bacteria from settled effluent were used as the inoculum, following gradual adaptation showed degradation of 87 and 84% at concentrations of 5 and 10 ppm respectively. It is noted that inadequate controls were present in this study.

Degradation of tetrachloroethylene using overland filtration resulted in 88% elimination at an initial tetrachloroethylene concentration of 70 ppb. The primary, sand filtered discharge of a university wastewater treatment facility was initially fed onto a grass covered filtration area for 2.5 months. Again, no control runs were carried out and it is uncertain whether the result was due to volatilisation, adsorption or biodegradation.

7.4.2 Anaerobic degradation

The following anaerobic degradation discussion is based on results reported in the BUA report (1993). Several studies are reported in this reference and are summarised below.

Anaerobic batch culture experiments lasting 8 weeks showed almost complete degradation from an initial concentration of 160 ppb. The major degradation product detected was trichloroethylene.

Anaerobic degradation under methanogenic conditions over 18 months showed, following an acclimatisation period around 9-12 weeks and a retention time of 2.5 days, 86% elimination, with an initial inflow concentration around 18 ppb.

A closed continuous flow through system with adapted, fixed bed columns demonstrated complete transformation of tetrachloroethylene by reductive dehalogenation.

With initial concentrations of 25-28 ppb, degradation by bacteria from the anoxic aquifer sludge of a closed-down landfill was investigated. A mixed culture with 3-chlorobenzoate as a carbon source degraded over 40% of the tetrachloroethylene after 5 months while bacteria without a primary substrate only achieved 10% degradation.

In contrast, degradation by a pure culture of a dehalogenating bacterial strain amounted to only 4% after 5 months (with a primary substrate). Pure bacterial cultures were unable to degrade the substance at all.

It may be concluded that anaerobic degradation will form a significant process for tetrachloroethylene removal where microorganisms have adapted to the chemical.

7.4.3 Bioaccumulation

The BUA report states tetrachloroethylene is attributed with no or only a low potential for bioaccumulation (BUA, 1993). This is largely supported by bioconcentration factors obtained from the US EPA Ecotox Database (US EPA, 2000) summarised below:

Table 7 - Bioconcentration factors for tetrachloroethylene

Species	Duration	Conditions	BCF	Exposure
Heterosigma akashiwo Algae	72 h	Static	BCFD=280-312	11-220 ppb
Skeletonema costatum Marine diatom	72 h	Static	BCFD=113-118	11-500 ppb
Lepomis macrochirus Bluegill	1-21 d	Flow through	BCF=49	3.43 ppb

BCFD= Bioaccumulation Factor Dry Weight.

However, other bioconcentration factors reported in the BUA report (1993) indicate tetrachloroethylene to be more highly concentrating than this. BCFs of 1,500-3,600 are reported for the gills of a roach species, bream and carp, while a BCF as high as 4800 is provided for the muscle of a carp species. Exposure levels of the organisms during these tests were significantly higher than those shown in the above table, with exposure up to 8,328 ppb in the carp demonstrating the highest BCF.

Exposure data are not available for all studies, and as such, conclusions in respect to whether tetrachloroethylene accumulation is stronger in freshwater or seawater fish cannot be drawn.

Only low bioconcentration factors are reported in Verschueren (1996) with values of 115 (rainbow trout), 62 (fathead minnow) and 39 (rainbow trout). Exposure levels are not provided.

Howard (1990) estimates a BCF of 226 based on the Log Kow and concludes tetrachloroethylene will not be expected to significantly bioconcentrate in aquatic organisms.

7.5 Summary of environmental fate

At equilibrium, >99% of released tetrachloroethylene is expected to partition to the atmosphere. The most important route of tetrachloroethylene degradation is its photodegradation by hydroxyl radicals in the atmosphere where relatively slow half-lives between 16 and 160 days may be predicted depending on the hydroxyl radical concentration and rate constant. Principal breakdown products are likely to be phosgene and trichloracetyl chloride.

For elimination of tetrachloroethylene from water, the most significant removal process is likely to be volatilisation with half-lives expected to be less than 3 weeks. Biodegradation under aerobic conditions has not been demonstrated. The most important biological degradation route is under anaerobic conditions by adapted microorganisms. On account of its physicochemical properties, under environmentally relevant conditions, tetrachloroethylene is not expected to hydrolyse.

Removal from soil is expected to be relatively rapid and largely due to volatilisation. Soil sorption is not expected to be significant, and leaching of tetrachloroethylene to groundwater may be expected. In groundwater, it may be subject to anaerobic degradation or may persist over a period of several years.

Bioaccumulation is unlikely to be significant.

7.6 Predicted environmental concentrations

7.6.1 Atmosphere

Point source:

Release estimates (section 7.2.1) show up to 18000 kg tetrachloroethylene is released from a single point source in one year. Recognising only a very small sample size for point sources (only 5 reporting facilities provided NPI input during the reporting period), and for a worst case, an atmospheric PEC will be calculated assuming a single annual point source release to be double this at 36000 kg per annum.

A PEC_{local} for air via point source emissions from tetrachloroethylene can be calculated using the methodology from the EU Technical Guidance Document (European Commission, 1996). Estimates are at 100 m from the point source and are derived as follows:

$C_{air}(mg/m^3) = Emission.Cstd_{air}$

where:

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

Emission = emission rate to air (kg/d)

$Cstd_{air}$ = Standard concentration in air at source strength of 1 kg/d = 2.78×10^{-4} mg/m^3.

An annual release of 36000 kg translates to a daily release of 120 kg assuming 300 days operation per annum. This gives a predicted tetrachloroethylene concentration at 100 m from the source of 33.4 µg/m^3.

Based on the conversion factor for tetrachloroethylene, this is a concentration in air of 4.9 ppb at points 100 m from the point source.

Urban air concentration:

Some urban air data is attainable from the NPI, but this is incomplete. The estimated releases of tetrachloroethylene were reported for several air sheds for 1998-99, and these are summarised in Table 8.

Table 8 - Estimated releases of tetrachloroethylene by air shed, 1998-99

Air shed	1998-99 estimated annual release to air (kg)
Adelaide, SA	133000
Hobart, TAS	19500
Kalgoorlie, WA	5540
Perth, WA	147000
Port Phillip Region, Vic	694670
SE Queensland, QLD	82000
Sydney Newcastle Wollongong, NSW	370000

Further interrogation of the NPI database reveals the highest amount of tetrachloroethylene expected to be released in any of the air sheds falls within the range of 1000-10000 kg/km^2 annually.

As a worst case, it will be assumed the maximum 10000 kg is released to the atmospheric compartment above a 1 km^2 urban environment. Following the methodology described in Connel and Hawker (1986), the volume of air in this compartment will be 6.14×10^9 m^3. With a daily release (300 days per annum) of 33.3 kg, the atmospheric concentration may be calculated at 5.4 µg/m^3, or 0.8 ppb.

Comparison with measured values:

Australian monitoring/modelling data:

The Victorian EPA has undertaken a review of studies performed in Australia and New Zealand on Hazardous Air Pollutants (Vic EPA, 1999). The results for tetrachloroethylene outlined in this document are summarised below. All figures have been converted to ppb.

Table 9 – Measured tetrachloroethylene concentrations in Australian urban air

Area	Area sampled	Year sampled	Description	Results (ppb)
Melbourne	General urban	1994	24 hours average	<0.2-1.1
Sydney	General urban	1992-93	10 min	2.8
		1995	24/48/72 hours average	ND-0.22
	Industrial	1994	No information	Up to 0.0012
Brisbane	General urban	1988	30 minute	0.02-1.42
Launceston	General urban	1994	No information	Up to 0.21

ND=not detected

In addition to this, a recent document provides monitoring for various air toxics including tetrachloroethylene in Perth (Government of Western Australia, 2000). For this report, 157 air samples were collected between March 1997 and November 1998 from the Perth metropolitan area and analysed by gas chromatography-mass spectrometry (GC-MS). The study involved collection of air samples from four monitoring stations and two other sites in the Perth metropolitan area. Year round sampling was conducted in one suburb, Duncraig, and Queen's Building in the CBD. Other sampling sites were Swanbourne (coast) and Hope Valley, downwind of the Kwinana industrial area. Some samples were collected from North Fremantle downwind of petroleum storage tanks, and from Gooseberry Hill on the Darling Scarp. Results are summarised below.

Table 10 - Tetrachloroethylene detections from Perth air monitoring

Sample location	Number of samples	Number of detections	Concentration (ppb)
Queens Building (CBD)	54	3	018, 0.17, 0.45
Duncraig	54	1	0.21
Hope Valley	23	1	0.45
Swanbourne	18	1	0.22

No detections were found from 4 samples in North Fremantle and 4 samples in Gooseberry Hill.

The annual average detected tetrachloroethylene concentration in Perth during the course of this study is stated in the report as 0.22 ppb with the maximum 24-hour average concentration of 1.57 ppb.

NSW EPA has undertaken 24-hour atmospheric monitoring, on a six-day cycle, during 1995 to 1998. The monitoring was conducted at 13 sites around Sydney, Wollongong and Newcastle, and included central business district, suburban and urban fringe/rural sites. Whilst 62 of 741 samples measured concentrations of tetrachloroethylene at or above the limit of detection (0.2 ppb), the annual average concentration at all sites was less than 0.2 ppb. (NSW EPA, 2001 personal communication).

Comparison of modelled urban atmospheric PEC to monitored data

The level of 0.8 ppb for a model urban centre derived above is within the range of results reported through monitoring studies in Australian urban centres.

Tetrachloroethylene can be detected in the atmosphere worldwide with its concentration being in the ng to µg range. The main sources of these emissions are manufacturing and processing plants in the northern hemisphere. However, distribution is rapid so tetrachloroethylene can also be detected in clean-air areas. Significant differences in concentration are found between the northern and southern hemispheres, city and rural air and continental and ocean air (BUA, 1993).

Northern hemisphere monitoring data show a range in tetrachloroethylene of 0.103 to 0.385 $\mu g/m^3$ (0.015 ppb to 0.057 ppb) while the range for Southern hemisphere readings are 0.021-111 $\mu g/m^3$ (0.003 ppb to 16.4 ppb). This difference may be interpreted as being due to the distribution of emission sources (BUA, 1993).

Ambient levels in cities in the United States generally range from 0.035-1.3 ppb (ASDTR, 1995), which compares favourably with the urban air concentration predicted above.

7.6.2 Surface water

Considering the use pattern of tetrachloroethylene in Australia, some release to water must be assumed. NPI information suggests this is minimal and the discussion on use pattern (section 6) also leads to this conclusion.

Where release does occur to sewer, the level of removal expected within a sewage treatment plant can be estimated. The Simpletreat model predicts that for a non biodegradable chemical with tetrachloroethylene's Log Kow and Henry's Law Constant of 1,237-1,733 $Pa.m^3/mol$, in the order of 90% will be stripped to air with the remainder remaining in the effluent.

Therefore, concentrations in receiving waters may be anticipated to be very low due to the minimal expected release to water and the likely high removal of the chemical during residence in the sewage treatment plant.

Comparison with measured values:

No current Australian monitoring data have been provided.

Based on 1984 data, tetrachloroethylene is stated to be detected in virtually all surface waters. In springs and streams a mean concentration of 0.01 ppb has been found (BUA, 1993). In a 1985 publication, concentrations ranging from <0.1 to >1,300 ppb were provided for surface waters (BUA, 1993).

Further data are provided in the BUA report (1993). Tetrachloroethylene has been detected in surface waters at a mean concentration of 0.5 ppb although it is not stated where the samples were from or how many were taken. In built-up areas, concentrations ranged from 1.5-20 ppb. A study designed to establish the distribution of various concentration ranges of tetrachloroethylene in and around Berlin (published in 1990) showed 61% of sample sites with <0.2 ppb, 25% with 0.21-1.0 ppb, 13% with 1-5 ppb and 1% with 5-10 ppb. Less than 0.5% of sites sampled had concentrations in excess of 10 ppb.

According to a 1982 publication, concentrations of tetrachloroethylene in water of the open ocean are about 0.01 ppb. For coastal waters, a maximum tetrachloroethylene concentration of 0.15 ppb was given. Samples of sediment from coastal waters show "typical" levels of 1 ppb (BUA, 1993).

7.6.3 Groundwater

Tetrachloroethylene is a known contaminant in several provinces in Canada, often as a result of its inappropriate disposal and release from drycleaning facilities or landfills (Environment Canada, 1993). It has also been detected in groundwater samples in the USA. While Australia does not produce tetrachloroethylene and uses comparatively less than the major Northern Hemisphere countries, tetrachloroethylene may be present in groundwater from past use, where it will persist. For example, the NSW EPA has detected tetrachloroethylene in groundwater in Sydney and country locations, in relation to contaminated sites. In most cases, it appears that the contamination was the result of using tetrachloroethylene as a solvent degreaser. Contaminated sites are assessed and measured according to the National Environment Protection Measure on Assessment of Site Contamination (NSW EPA, 2001 personal communication).

From an environmental perspective, concentrations in groundwater are not expected to be at levels likely to impact on organisms and when released to surface waters, the chemical is expected to volatilise readily to the atmosphere.

7.7 Public exposure

7.7.1 Import, transport and storage

There is little potential for exposure of the public as a direct result of tetrachloroethylene importation, with transport accidents or spills being the main potential source. Should a major spill occur, there is the potential for extensive exposure of the public, particularly given the volatility of tetrachloroethylene.

7.7.2 Drycleaning

There is potential for public exposure in drycleaning outlets when clothes are dropped off or picked up, in cars transporting drycleaned clothes home, and in the home when drycleaned clothes are stored. Individuals may also be exposed to tetrachloroethylene when wearing clothes that have been drycleaned, or when shopping, particularly in indoor shopping centres which have drycleaning outlets that clean the clothes on site.

Information available on tetrachloroethylene levels in and around drycleaning establishments in the USA (US EPA, 1998) indicate that ambient levels around drycleaning outlets can vary considerably. The levels vary with the type of machine used (transfer machines or dry-to-dry machines), with the condition of the machine, and with the ventilation and condition of the building. Levels in residences located in buildings with drycleaning machines ranged from 0.02 to 62 mg/m^3 (2.9 ppb to 9.0 ppm) in residences above transfer machines, from 0.16 to 55 mg/m^3 (0.02 ppm to 8.0 ppm) in residences above vented dry-to-dry machines, and from 0.0007 to 1.9 mg/m^3 (0.1 ppb to 0.3 ppm) in residences above non-vented dry-to-dry machines.

It was noted that the highest levels of tetrachloroethylene were associated with drycleaning machines in poor condition. It is possible that in these machines, seals may not have been operating properly, and thus emissions of tetrachloroethylene may have increased. In Australia, according to the Drycleaning Institute of Australia, transfer machines (first generation) were never used, and only a few machines with conventional condensers and venting (second generation) are still in use. The majority of machines in use in Australia are non-vented dry-to-dry machines with refrigerated condensers. If these machines are considered to be similar to those used in the USA, the range of levels found in buildings with such machines would be expected to range from 0.0007 to 1.9 mg/m^3 (0.1 ppb to 282 ppb). The range includes the calculated expected ambient levels in air in Australia (0.8 ppb), see section 7.6.1.

A study of emissions of tetrachloroethylene from drycleaned fabrics (Tichenor et al, 1990) found that bringing drycleaned clothes into a residence will increase the levels of tetrachloroethylene, particularly during the first day after cleaning. Levels in the closet where clothes are stored were highest (up to 3 mg/m^3, 0.4 ppm), with levels in the bedroom containing the closet at up to 0.2 mg/m^3 (0.03 ppm), and levels at the other end of the house (average 3-bedroom house) being 0.08 mg/m^3 (0.01 ppm), with these levels peaking on the second day after cleaning. Airing the clothes with the bag removed did not change the amount of tetrachloroethylene released, and there was no difference found between clothes stored in the drycleaning bag or with the bag removed.

The variability observed was considered mainly to be due to the amount of tetrachloroethylene remaining in the clothes after drycleaning. The amount of air exchange occurring in the house may affect the levels of tetrachloroethylene, as venting will lower levels. Tetrachloroethylene may be taken up by other furnishings in the house; this is likely to be released as ambient levels drop, and thus will not affect the total release of tetrachloroethylene.

A study on the effect of wearing drycleaned clothes has been conducted (US EPA 1998). In this study, measured concentrations ranged from 4.8 mg/m^3 (0.69 ppm) to below detection levels, with the median concentrations being 0.032 mg/m^3 (4.6 ppb) for charmeuse blouses, 0.043 mg/m^3 (6.2 ppb) for men's cotton sweater, 0.094 mg/m^3 (13.6 ppb) for silk blouses and 0.22 mg/m^3 (31.9 ppb) for women's blazers. The results were extremely variable.

Another study on tetrachloroethylene (US EPA 1998) involved 24-hour concentrations measured by the use of a personal sampler. The arithmetic mean personal exposure was 0.017 mg/m^3 (2.5 ppb). This included one very high concentration (1.6 mg/m^3; 0.23 ppm). If this measurement was excluded, the mean personal exposure was 0.012 mg/m^3 (2 ppb). These levels were higher than the measured outdoor concentrations in the same areas (0.009 mg/m^3; 1.3 ppb). Exposure to drycleaned clothes, and non-ambient sources such as paints solvents and cleaning materials were considered to contribute to the higher concentrations.

7.7.3 Other tetrachloroethylene sources

Some other sources of tetrachloroethylene in Australia may contribute to public exposure. A number of products, containing tetrachloroethylene in varying concentrations are available to the public for use in car maintenance. These are a tyre shine, a brake cleaner and a spray grease. In the tyre shine and spray grease, tetrachloroethylene is present as a solvent for other ingredients, while in the brake cleaner tetrachloroethylene is the only component other than the aerosol propellant gas. These products may be expected to be used by individuals interested in car maintenance. Brake cleaner and spray grease would be expected to be used relatively infrequently (possibly from 1 to 6 times per year). Tyre shine products are more likely to be used on a short term intermittent basis, but may potentially be used on a weekly basis by car enthusiasts, and this may result in moderate levels of exposure.

Cleaning products containing tetrachloroethylene may be used by the general public. A cleaner for electric motors containing 95 to 99% tetrachloroethylene is available to the general public. As only a small quantity of this product was imported in 1999, and its main use is industrial, only limited public exposure would be expected. A carpet stain removal product containing 12% tetrachloroethylene is also available for consumer use. The product is designed to be rinsed from the stain with water after application, which decreases the potential for extended exposure to tetrachloroethylene.

Tetrachloroethylene is used in the textile industry to scour fabrics both prior to and during dyeing processes. It would be expected that any tetrachloroethylene remaining on the fabric after these processes would have volatilised before public contact with the fabric.

8. Health Effects and Hazard Classification

This section is limited to a brief overview of the health effects and classification of tetrachloroethylene and is intended as background information for the conclusions and recommendations that follow. It is based on the US Department of Health and Human Services Agency for Toxic Substances and Disease Registry, Update on Tetrachloroethylene (ATSDR) 1997; “Cleaner Technologies Substitutes Assessment: Professional Fabricare Processes” (US EPA Office of Pollution Prevention and Toxics, 1998), the International Agency for Research on Cancer (IARC) monograph volume 63 (IARC, 1995) and the OECD SIDS Report (OECD, 1996).

8.1 Toxicokinetics and metabolism

Inhalation is the primary route of exposure to tetrachloroethylene. The chemical is readily absorbed following inhalation of its vapour and oral and dermal exposure to the liquid. Uptake of tetrachloroethylene vapour by the skin is minimal.

Tetrachloroethylene is highly lipophilic resulting in distribution to the fatty tissue. The half-life of tetrachloroethylene in human adipose tissue is estimated to be 55 hours. It is found in human and animal milk and has been shown to cross the placenta and distribute to the foetus in mice.

Once absorbed its metabolism is important, as much of the toxicity of tetrachloroethylene is generally considered to result from its reactive metabolites. It has been shown, for example, that parameters of liver toxicity such as liver weight increase, accumulation of triglycerides and serum glutamate pyruvate transaminase (SGPT) vary in direct proportion to the amount of tetrachloroethylene metabolised.

Metabolism of tetrachloroethylene in humans and rodents is relatively limited. Rats metabolise tetrachloroethylene to a greater degree than humans and mice to a greater degree than rats. In humans only 1-3% of absorbed tetrachloroethylene is metabolised. Oxidation is the major pathway in humans and rodents giving rise to trichloroacetic acid via the Cytochrome P-450 system, most probably in the liver. Ethnic differences in the rate of metabolism have been found in workers exposed to tetrachloroethylene. One explanation may be that Cytochrome P-450 exists in numerous isoforms and some isoforms further subdivide into different isotypes, expression of which is genetically based.

Rodents have a second, minor metabolic route, namely glutathione conjugation in the liver producing 1,2,2-trichlorovinylglutathione. This metabolite is further transformed in the kidney by β-lypase. Glutathione conjugation could not be detected in human liver cytosol and this pathway may not be a relevant route in humans. The metabolism of tetrachloroethylene in animals and humans is saturable. As the dose of tetrachloroethylene administered increases, the glutathione pathway in animals becomes more important as the oxidative pathway is saturated.

In humans, metabolism to trichloroacetic acid appears to plateau at concentrations above 100 ppm. In a study where mice were administered tetrachloroethylene by gavage, the amount of total metabolites in urine plateaued at doses above 1,000 mg/kg/day.

The primary route of excretion in humans and rodents is exhalation of unmetabolised tetrachloroethylene. Elimination of tetrachloroethylene and its metabolites in the breath and urine, respectively, is slow. The biological half-life of many metabolites was approximately 6 days in workers.

8.2 Effects on experimental animals and in vitro bioassays

Tetrachloroethylene has low acute toxicity following exposure by inhalation and gavage. In mice, LC50 values range between 2445 ppm and 5200 ppm following 4 hours inhalation. Rats showed an LC50 of 2445 ppm under the same conditions. Single oral dosing gave LD50 values of 2400 mg/kg to 13000 mg/kg bw (body weight) in rats and ranges from 8800 mg/kg bw to 10800 mg/kg bw in mice. In acute studies death was preceded by tremors, ataxia and CNS depression.

Skin and eye irritation has been observed in animal studies. The only sensitisation study, a 'split-adjuvans' test in guinea pigs, was negative.

The main target organs following repeated exposure are the liver in mice and kidney in the rat. The main liver effects are fatty degeneration, enlargement, cellular vacuolisation and necrosis. The main kidney effects are kidney tubular karyomegaly, a low incidence of renal tubular hyperplasia in male mice, toxic nephropathy characterised by degenerate changes in the proximal convoluted tubules with cloudy swelling, fatty degeneration and necrosis of the tubular epithelium and hyalin intraluminal casts. Protein droplet accumulation and increased $\alpha_{2\mu}$-globulin have been observed in male but not female rats. Tetrachloroethylene induced peroxisomal proliferation in mouse liver following oral exposure, and a marginal response was observed in mouse kidney and rat liver. The OECD SIDS report identified a lowest no observed adverse effect level (NOAEL) of 300 ppm for systemic toxicity in the rat (OECD, 1996).

Neurological effects following inhalation exposure in animals are similar to those found in humans (see below). At high concentrations hypo- and hyperactivity, ataxia and loss of consciousness have been reported in rodents. There is some evidence that animals may adapt to the neurological effects of tetrachloroethylene.

Reproductive effects included a decrease in the number of liveborn pups (at 1,000 ppm) in an inhalation multi-generation rat study. Foetal toxicity was observed in rats and mice in an inhalation developmental study (300 ppm only dose level tested). The effects were not reported in a similar study in rats and rabbits conducted at a higher dose.

Mice are not considered to be an appropriate model for humans because of the differences in rates of metabolism and peroxisome proliferation response. Rats are considered to be a more appropriate model and the NOAEL identified is 300 ppm, based on a good quality, 2-generation study (OECD, 1996).

The mutagenic potential of tetrachloroethylene has not been clearly demonstrated. Tetrachloroethylene has been widely tested in in vitro and in vivo studies, with most studies being negative or weakly positive. Available data on some metabolites of tetrachloroethylene indicate these metabolites are mutagenic. However the relevance of these metabolites to human toxicity has not been established. For example, the relevance of the metabolite trichloroacetic acid and associated mouse liver tumours to humans is questionable (NICNAS, 2000).

The evidence for carcinogenicity is based primarily on the results of two long-term studies in rodents. In a gavage study in rats and mice tetrachloroethylene induced a statistically significant increase in the incidence of hepatocellular carcinomas in mice. No increases in tumour incidences were seen in rats, but the rat studies were deemed inconclusive.

An inhalation study in rats and mice found significantly increased incidences of mononuclear cell leukaemia in female and male rats. Male and female mice showed significantly increased incidences of hepatocellular adenomas and carcinomas. Male rats (F344/N) showed an increased incidence of renal tubular cell tumours compared with controls, though this did not reach statistical significance. However, these tumour types are uncommon in this rat strain, exhibiting low historical incidences.

8.3 Human studies

Tetrachloroethylene has low acute toxicity in humans. Acute exposure to high concentrations of vapour causes CNS effects. Reports of dizziness, mood changes, faintness, headache or nausea have been reported at concentrations above 100 ppm of tetrachloroethylene over varying exposure durations. Acute exposure to tetrachloroethylene at concentrations above 2,000 ppm has resulted in collapse, coma, seizures and even death (presumably at very high levels). Respiratory irritation has been observed in humans exposed to tetrachloroethylene at concentrations greater than 216 ppm. Subchronic and chronic exposure to tetrachloroethylene caused CNS effects at and above 50 ppm. Effects observed include small decrements in mean scores of neurobehavioural tests. In one study the loss of colour vision was observed at 7 ppm (average concentration), however the study had several deficiencies.

Following accidental exposure to anaesthetic concentrations of tetrachloroethylene vapour, symptoms of renal dysfunction including proteineuria and haemateuria have been seen. Weak or no renal effects have been reported with chronic occupational exposure (average exposure 10 to 21 ppm). The significance of these small effects is unclear as they may represent an adaptive response.

Liver effects have also been reported following accidental acute exposure to high concentrations of tetrachloroethylene. Studies in drycleaning workers exposed to tetrachloroethylene in the workplace air have shown the liver to be a target organ for toxicity in humans. Subtle liver effects were observed as statistically significant increases in total serum gamma glutamyltransferase (GGT) and parenchymal changes (mean exposure levels 11-16 ppm). However, there were no changes in other enzymes measured and no clinical signs of liver disease. Available human data is inconclusive with regard to the potential of tetrachloroethylene to cause developmental and reproductive toxicity. Some studies have found increases in spontaneous abortions, menstrual disorders, decreased numbers of pregnancies and abnormalities in sperm in workers or spouses of workers exposed to tetrachloroethylene.

Due to the limitations of the studies and the presence of other solvents, the relevance of these findings to tetrachloroethylene exposure is unclear.

The relationship between exposure to tetrachloroethylene and cancer risk comes from a number of cohort studies. Non-Hodgkin's lymphoma, oesophageal and cervical cancers were consistently reported in several studies. Most of the studies however, have been conducted in populations exposed to a variety of solvents together with other confounding factors such as smoking. Additionally, the numbers of observed cases of these cancers in the studies were too small to draw statistically valid conclusions. These limitations make it difficult to ascribe the results to tetrachloroethylene alone, and establish a causal relationship between tetrachloroethylene exposure and cancer in humans.

8.4 Hazard classification

Currently tetrachloroethylene is classified on the NOHSC List of Designated Substances (NOHSC, 1999a) with the following risk phrase:

R40 Possible risk of irreversible effects (carcinogen category 3)

A substance is included in category 3 if there is some evidence from appropriate animal studies that human exposure can result in the development of cancer, but this evidence is insufficient to place the substance in category 2 (NOHSC, 1999b).

EU classification

The *European Commission Working Group on the Classification and Labelling of Dangerous Substances* at the May 2000 meeting agreed the following classifications for tetrachloroethylene:

- R40 – possible risk of irreversible effects (carcinogen category 3)
- R38 – irritating to skin
- R67 – vapours may cause drowsiness or dizziness

The Working Group agreed to consider the advice of the Specialised Experts on fertility and developmental toxicity when available. When the classification of tetrachloroethylene is finalised by the Working Group it will be forwarded to the EU for adoption.

8.5 Carcinogenicity

There is a great deal of debate regarding the carcinogenicity of tetrachloroethylene. The conclusions of several overseas agencies are summarised below.

IARC

Tetrachloroethylene has been evaluated by the International Agency for Research on Cancer (IARC) in 1978, 1987 and 1995. The IARC Working Group in 1995 (IARC, 1995) concluded that there is limited evidence in humans but sufficient evidence in experimental animals for the carcinogenicity of tetrachloroethylene. The chemical was evaluated overall as a Group 2A carcinogen (probably carcinogenic to humans).

In making the overall evaluation, the Working Group considered the following:

(i) Although tetrachloroethylene is known to induce peroxisome proliferation in mouse liver, a poor quantitative correlation was seen between peroxisome proliferation and tumour formation in the liver after administration of tetrachloroethylene by inhalation. The spectrum of mutations in proto-oncogenes in liver tumours from mice treated with tetrachloroethylene is different from that in liver tumours from mice treated with trichloroethylene.

(ii) The compound induced leukaemia in rats.

(iii) Several epidemiological studies showed elevated risks for oesophageal cancer, non-Hodgkin's lymphoma and cervical cancer.

OECD SIDS Report

OECD concluded that overall, a variety of epidemiological studies have shown no good evidence for an increased risk of carcinogenicity in humans resulting from exposure to tetrachloroethylene. These studies are limited because of several factors including latency, confounding exposures and biological plausibility.

The mechanism of tumourogenesis does not involve a direct mutagenic action of tetrachloroethylene, based on genotoxicity studies.

The increase in mononuclear cell leukaemia in male rats was dismissed because of the high background rates, the lack of a dose-response trend, the increases found were not convincingly related to tetrachloroethylene and in any case this leukaemia is not considered to be of concern in relation to human health.

For the mouse liver tumours, the mechanism is likely to involve peroxisomal proliferation, an effect to which humans are not responsive. For the rat kidney tumours, the mechanism is likely to involve the glutathione conjugation pathway, which is of little importance at low tetrachlorethylene exposures, but becomes increasingly significant in rats as the oxidative pathway to trichloroacetic acid becomes saturated at higher levels. The liver tumours in mice and kidney tumours of mice are not of significance to human health.

Taking the human and animal findings together, the OECD concluded that there is no evidence that repeated exposure of humans at occupationally-relevant levels carries with it any increased risk of developing cancer (OECD, 1996).

US EPA

The US EPA concluded that the epidemiological studies are inadequate for establishing a causal relationship between tetrachloroethylene exposure and cancer in humans because the studies have generally involved mixed exposures, limitations in the study designs and exposure characterisation, impact of potential confounding factors and statistical considerations.

The US EPA acknowledges the controversy that surrounds each of the tumour types observed in animal studies, regarding their relevance to humans, and that there is some evidence to support each of the proposed mechanisms as follows:

- Mononuclear cell leukaemia is a common tumour that occurs spontaneously in F344/N rats and the tumour has no human correlate.

- Liver tumours may be related to peroxisome proliferation and toxicity of trichloroacetic acid (TCA). Human liver cells are even less efficient metabolisers of tetrachloroethylene to TCA than rats and are generally unresponsive to peroxisome proliferating agents.
- Kidney tumours in rats may be due to the accumulation of the protein $\alpha_{2\mu}$-globulin in renal proximal tubular cells, but may also be related to a glutathione-β-lyase conjugation pathway. There is some evidence that the conjugation pathway is active in humans.

US EPA concluded that there are quantitative and qualitative gaps in the supporting data and several other mechanisms, such as mutagenicity of metabolites, may contribute to the carcinogenicity of tetrachloroethylene. In addition, there is evidence from recent epidemiological studies, which have limitations. The view of the US EPA Science Advisory Board is that there is a concern for carcinogenicity for high tetrachloroethylene exposures and this is consistent with the uncertainties regarding the modes of action of the associated tumour types (US EPA, 1998).

9. Environmental Effects

9.1 Effects on organisms in the environment

The following results in this section have been obtained from the US EPA's Ecotox Database (US EPA, 2000) and the German BUA Report (1993). Discussions relating to selected results have been paraphrased from the BUA Report as no details are available from the ECOTOX Database. Environment Australia has not obtained any of the publications referenced in either of these source documents.

9.1.1 Aquatic toxicity

Toxicity to fish

Acute toxicity results were available for 7 species of fish in a range of both static and flow through tests. LC50 values ranged from 1.6 ppm in a static test on medaka *(Oryzais latipes*) to 29 ppm in a static test on sheepshead minnow (*Cyprinodon variegatus*).

Chronic results were found for 3 species, all performed under flow through conditions. Rainbow trout was shown to be the most sensitive species tested with a 32 day LC50 of 1.4 ppm and a maximum acceptable toxicant concentration of 0.5-1.4 ppm.

These results indicate tetrachloroethylene may be considered slightly to moderately toxic to fish based on acute effects (Mensink, 1995).

Toxicity to aquatic invertebrates

The teratogenic effect of tetrachloroethylene was studied in nauplii, stages I-III of the brine shrimp. The larvae were not fed and exposed to concentrations between 0.25-25 mg/L in artificial seawater. Sensitivities changed significantly depending on growth stage with LC50 values ranging from 0.33-23.2 ppm. There was not enough information on the test available to determine which result corresponds to which growth stage. Further, it is stated that this test is not precise for volatile substances such as tetrachloroethylene.

Other acute tests available for aquatic invertebrates are indicative of moderate to slight toxicity with EC50/LC50 values ranging from 7.5 ppm (*Daphnia magna*) to 30.8 ppm to the midge *Tantytarsus dissimilis*. Tetrachloroethylene showed only very slight toxicity to one invertebrate ciliate species *Tetrahymena pyriformis* with an EC50 of 100 ppm.

An unpublished chronic study on *Daphnia magna* is described in the BUA report (1993). The study was a 21-d reproduction test carried out with nominal concentrations between 0.16-40 mg/L. At a nominal concentration of 2.5 mg/L, no progeny were observed within the 21 days of the test, while in the control, around 89 progeny/female were observed by day 7-8. A NOEC of 1.25 mg/L was determined. Maternal mortality was 100% after 21 days exposure.

One result for the Australian barnacle *Eliminius modestus* is described in the BUA report (1993). Acute toxicity was tested towards the nauplii of these organisms under static conditions with a 48 h LC50 of 3.5 mg/L determined. However, it is noted the test medium did not correspond with standardised conditions indicating that a comparison with other results is limited.

Generally, tetrachloroethylene may be considered to be moderately to slightly toxic to aquatic invertebrates based on acute effects (Mensink, 1995). Indications of high toxicity are present depending on the life stage of organisms but there is not enough information to draw firmer conclusions.

Toxicity to algae and aquatic plants

Table 11 - shows results of tests conducted on algae and aquatic plants.

Table 11 - Toxicity to algae and aquatic plants

Species	**Duration**	**Condition**	**Result** (mg/L)
Selenastrum capricornutum Green algae	96 h	No Record	EC50>500
			NOEC<500
Skeletonema costatum Marine diatom	96 h	No Record	EC50=509
Heterosigma akashiwo Algae	48 h	Static	EC50~0.2

The test on *S. capricornutum* is stated as a 96-h cell multiplication inhibition test, in which the reduction in chlorophyll *a* content was measured. No further details in respect to test conditions are provided (BUA, 1993).

A 7-week field study conducted with phytoplankton under static conditions is described in the BUA report (1993). It is stated that after just a few days, two autotrophic species had died out although no details relating to concentrations and species tested are provided.

A comprehensive field study described in the BUA report (1993) further indicates toxicity of tetrachloroethylene to algae and aquatic plants, and this is discussed in section 9.1.2 – Ecosystems.

9.1.2 Ecosystems

The following discussion has been obtained from the BUA Report (1993). These available studies provide insight into how tetrachloroethylene may impact on whole ecological communities.

An 11-week field study of "enclosures" in an experimental pond compared changes in species composition and population density of phyto- and zooplankton, as a result of exposure to tetrachloroethylene at concentrations of 0.8 and 1.6 mg/L. The target concentrations, which were considerably lower than those applied in the laboratory, were achieved within 5 days of commencing the experiment. The study had the following methodology: 30 days before beginning to add tetrachloroethylene, the pond was divided into 4 subsystems using open-ended

PVC cylinders. The target concentrations were maintained through continuous application over a period of 70 days after being reached.

The various species were classified as either producers (algae) or consumers (rotifers, small crustaceans, insect larvae and bacteria).

Measurements of primary production showed an initial short-term reduction in algal density, but from the second week on, a marked increase was observed. However, with respect to individual species, tetrachloroethylene had a marked toxic effect. Thus in the first few days among the producers, two algal species had died out, and among the consumers, the water fleas had died out. The higher tetrachloroethylene concentration also had a toxic effect on the copepod population (consumer) and the nauplius larvae, which in contrast to the control, almost disappeared. At the lower tetrachloroethylene concentration an increase in the reproduction rates was observed towards the end of the experiment. The authors interpret this finding as indicating a reaction of the organisms to stress.

Multiplication of one green algal species was severely inhibited during the first 40 days. Among the rotifers, the genera *Keratella* and *Synchaeta* died out after 3 and 33 days respectively. Tetrachloroethylene had a strong toxic effect on larvae of the mosquito, their development being severely inhibited compared to the controls at both test concentrations, although a sufficient supply of nutrients was available.

A dynamic Daphnia test conducted in the River Ruhr showed a marked effect on the animals' mobility. Increased concentrations of tetrachloroethylene (maximum concentration 12 µg/L) were reflected in reduced mobility of the test organisms. The Daphnia reacted with an immediate strong reduction in mobility, which returned to normal only after the concentration of tetrachloroethylene had dropped to 1 ppb (BUA, 1993). It is stated that these observations cannot be directly attributed to tetrachloroethylene although this may have had a triggering effect, since the lowest static laboratory 48 h EC50 above is 7.5 ppm, more than 1000-fold the concentration measured in the Ruhr. From the available analysis it isn't possible to determine whether this discrepancy is the result of volatilisation of tetrachloroethylene in the laboratory tests. Another source of uncertainty lies in not knowing whether laboratory tests were reported in nominal or measured concentrations.

Alternatively, the toxicity observed in field experiments may have been due to other harmful substances present in the river, and the possibility of a combined effect of tetrachloroethylene with other harmful substance must be considered (BUA, 1993).

It is claimed in the BUA report (1993) that the Daphnia investigated in the field had already been damaged by other substances present in the River Ruhr. Compared to Daphnia found in the River Rhine, those observed in the Ruhr showed considerably reduced mobility and retarded growth, as well as being colourless. This cannot be considered a very reliable test.

9.1.3 Terrestrial toxicity

Terrestrial invertebrates

Several soil organisms, including micro-organisms, invertebrates and plants, have been used to assess the toxicity of tetrachloroethylene after acute or prolonged exposure. Most of these studies have been conducted under non-standard conditions. NOECs are of the order of 1 mg/kg soil. Effects have been reported following exposure to tetrachloroethylene at 10 mg/kg soil for one plant species or 18 mg/kg for earthworms (ECETOC, 1999).

Terrestrial plants

A study reported in 1986 indicates that upon exposure to light, halogenated hydrocarbons may damage the photosynthetic apparatus of conifers. It was reported that, within 2 days of exposure to 40 µg/m^3 (5.8 ppb) under intensive UV radiation, the needles of *Picea abies* were chloritic. Similar effects were also reported for the sun-exposed leaves of a hornbeam shrub and spruce exposed to 1.72 ppb tetrachloroethylene over a 7-month period in which bleaching of chlorophyll in the *in situ* sunlit twigs was reported. The authors attributed the damage to the herbicidal action of TCA as either formed by the transformation of tetrachloroethylene exposed to UV radiation, or formed in the leaves after adsorption of the lipophilic tetrachloroethylene by the cuticle (ECETOC, 1999).

It should be recognised that chloroacetic acids (CAA) are widely distributed environmental pollutants. The major sources of CAA include formation in the atmosphere by photochemical degradation of chlorinated solvents (Berg et al., 2000). Therefore, tetrachloroethylene is only one of many contributing sources of chloroacetic acids.

Further studies with *Picea abies* under normal light conditions and exposure to 25 ppb tetrachloroethylene for 24 h showed reversible effects on photosynthesis as well as respiration and transpiration. The pigment content of the needles was not affected (ECETOC, 1999).

9.2 Summary of environmental effects

Following the guidelines from Mensink et al. (1995), and based on laboratory data, tetrachloroethylene may generally be regarded as slightly to moderately toxic to fish and aquatic invertebrates. The chemical may be expected to be highly toxic to some invertebrates depending on their life stage. Tetrachloroethylene appears practically non toxic to algae based on laboratory experiments.

Field testing showed ecosystems to be potentially far more sensitive to tetrachloroethylene exposure than laboratory results suggest. At relatively low concentrations, strong adverse impacts were noted on various algae and invertebrate species, including *Daphnia*, which demonstrated high sensitivity to the chemical. However, not enough information is available to adequately draw firm conclusions.

Several soil organisms, including micro-organisms, invertebrates and plants, have been used to assess the toxicity of tetrachloroethylene after acute or prolonged exposure. Most of these studies have been conducted in non-standard conditions. NOECs are of the order of 1 mg/kg soil. Effects have been reported following exposure to tetrachloroethylene at 10 mg/kg soil for one plant species or 18 mg/kg for earthworms.

It is suggested that tetrachloroethylene may have an adverse effect on the photosynthetic apparatus of conifers and other higher plants following exposure to tetrachloroethylene.

10. Regulatory Controls

The NOHSC National Model Regulations (NOHSC, 1994c) and Exposure Standards, (NOHSC, 1995) the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code) (FORS, 1998) and the Standard for the Uniform Scheduling of Drugs and Poisons (SUSDP, 1998) are documents that aim to promote uniform regulation throughout Australia by inclusion in the relevant State and Territory legislation. In general, these documents have been included in such legislation. The handling, storage and use of tetrachloroethylene are controlled through State and Territory legislation pertaining to workplace health and safety, local government, poisons, dangerous goods and protection of the environment.

10.1 Workplace hazard communication

10.1.1 Hazard classification

Under the NOHSC *List of Designated Hazardous Substances* (NOHSC, 1999a), tetrachloroethylene is classified as hazardous, carcinogen category 3, (R40).

10.1.2 Labels

Under the NOHSC *National Model Regulations for the Control of Workplace Hazardous Substances* (NOHSC, 1994c) and the corresponding State and Territory legislation, suppliers or employers shall ensure that all containers of hazardous substances used at work are appropriately labelled in accordance with the NOHSC *Code of Practice for the Labelling of Workplace Substances* (NOHSC, 1994a).

Tetrachloroethylene is classified as hazardous. Labels for containers of tetrachloroethylene should contain the following risk and safety phrases:

R40	Possible risk of irreversible effects
S2(1)	Keep out of reach of children
S23	Do not breath vapour
S36/37	Wear suitable protective clothing and gloves

Bulk storage vessels and tanks must be labelled according to the appropriate State or Territory dangerous goods regulation, generally with an affixed hazard sign or placard similar to the one required for road tankers under the Australian Dangerous Goods (ADG) Code.

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[1] the safety phrase is only necessary in situations where the general public could come into contact with the chemical

10.1.3 Material safety data sheets

Material Safety Data Sheets (MSDS) are the primary source of information for workers involved in the handling of chemicals. Under the NOHSC *National Model Regulations for the Control of Workplace Hazardous Substances* (NOHSC, 1994c) and the corresponding State and Territory legislation, suppliers of a hazardous chemical for use at work are obliged to provide a current MSDS to their customers. Employers must ensure that the MSDS provided by the supplier is readily accessible to employees with potential for exposure to the chemical.

10.2 Workplace control measures

Tetrachloroethylene is classified as a hazardous substance. According to the NOHSC National Model Regulations for the Control of Workplace Hazardous Substances (NOHSC, 1994), exposure to hazardous substances should be prevented or, where this is not practicable, adequately controlled, so as to minimise risks to health and safety.

In general, the control of worker exposure to any hazardous substance should be achieved through a hierarchy of control strategies comprising elimination, substitution, isolation, engineering controls, safe work practices, and personal protective equipment. Control measures are not exclusive and effective control usually requires a combination of these measures. In relation to tetrachloroethylene, particular attention must be paid to control measures that minimise inhalational exposure.

10.3 Occupational exposure standards

The current national occupational exposure standard for tetrachloroethylene in Australia is 50 ppm (340 mg/m^3) expressed as an 8 h TWA and 150 ppm (1,020 mg/m^3) for a short-term exposure limit (STEL), (NOHSC, 1995). STELs are for airborne concentrations averaged over a period of 15 minutes. A STEL should not be exceeded at any time during a normal 8-hour working day. The tetrachloroethylene standards were adopted by NOHSC in 1990 to prevent irritation and subjective complaints (TWA), and anaesthetic effects (STEL). Table 12 sets out a number of international occupational exposure levels.

The US Occupational Safety and Health Administration (OSHA) in 1989 established a TWA of 25 ppm for tetrachloroethylene replacing the former TWA of 100 ppm. However a 1992 US Appeals Court decision invalidated, on administrative grounds, a number of Rulings lowering various PEL's (including the one for tetrachloroethylene).

The American Conference of Governmental Industrial Hygienists (ACGIH) established in 1993, an 8 h TWA level of 25 ppm and an STEL of 100 ppm. The ACGIH arrived at this recommendation to provide a margin of safety in preventing discomfort and subjective complaints (TWA), and anaesthetic effects (STEL). In addition, these standards would provide a wide margin of safety in preventing possible liver effects. The ACGIH also concluded that in the absence of exposures which elicit liver injury, there was no expectation of human liver tumours (ACGIH, 2000).

Table 12 – International occupational exposure levels for tetrachloroethylene in ppm (after ACGIH, 2000)

Country	8 h TWA	STEL
Australia	50	150
Belgium	50	200
Denmark	30	-
Finland	50	75
France	50	-
Hungary	50	-
Ireland	50	150
Japan	50	-
The Netherlands	35	-
Sweden	10	25
Switzerland	50	100
United Kingdom	50	150
US ACGIH	25	100
US OSHA	100	200

10.4 National transportation regulation

Under the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (ADG Code), tetrachloroethylene (UN Number 1897) is classified in Class 6.1, Packing Group III (FORS, 1998). Class 6.1 comprises toxic substances. Tetrachloroethylene is assigned Packing Group III because of its low risk.

The ADG Code sets out various requirements relating to the transport of tetrachloroethylene by road or rail.

Road and rail tankers transporting bulk tetrachloroethylene and vehicles or rail rolling stock transporting packaged tetrachloroethylene must be placarded with class label 6 (‘toxic’). Bulk tankers must also display an emergency information panel containing additional information such as the proper shipping name of the chemical (‘tetrachloroethylene’), its UN Number, Hazchem Code and the name and telephone number of the consignor of the goods. The Hazchem Code for tetrachloroethylene is 2[Z]. The code reflects the initial emergency response recommended in case of fire, leakage or spillage. The number ‘2’ indicates that water fog or in the absence of fog, a fine spray should be used for fire fighting. The letter “[Z]” means that there is no risk of violent reaction or explosion; that emergency personnel should wear breathing apparatus in the event of fire only; and that any spillage should be contained so as to prevent the chemical from entering drains or water courses.

Under the ADG Code, road tankers used to transport bulk tetrachloroethylene must be constructed in compliance with Australian Standards AS 2809.1, and AS 2809.4 (Standards Australia, 1985 and 1990). Furthermore, they must be inspected externally and internally and hydraulically tested at intervals of not more than 5 years and carry a plate that attests to their compliance with the construction and testing requirements. Rail tankers transporting bulk material must comply with the requirements for road tankers. Rolling stock must be hydraulically tested and visually inspected as prescribed by the ARA Rolling Stock Manual.

The ADG Code also contains detailed provisions for the inner packaging and marking of packages containing small quantities of the chemical, such as bottles of reagent grade tetrachloroethylene distributed by road or rail.

As an example of State regulation based on the ADG Code, the NSW *Dangerous Goods Act 1975* regulates licensing of premises keeping dangerous goods, the storage and conveying of dangerous goods in vehicles, as well as the unloading of such substances at ports. The *Dangerous Goods (General) Regulations 1998* adopt goods listed as dangerous in the ADG Code as dangerous goods in NSW and adopt the labelling classifications of the ADG Code. As tetrachloroethylene is classified in group 6.1 Packaging Group III, of the Code, under the Regulations no more than 1000 litres may be stored in unlicensed premises. For quantities above this a license is required. From site visits conducted by NICNAS most drycleaning establishments would be unlikely to store more than 1000 litres of the chemical. Sites using the chemical are likely to also use other chemicals some of which could react dangerously if they come into contact with tetrachloroethylene. Drycleaners for example use several different chemicals for spotting and other operations. The storing of different classes of dangerous goods in the same area is controlled by the Regulations by adopting the requirements of *Australian Standard AS/NZS 3833:1998 – The storage and handling of mixed classes of dangerous goods in packages and intermediate bulk containers* (Standards Australia, 1998) which gives recommendations for storage of dangerous goods including those in class 6.1 and when two or more classes of goods are kept in the same area, recommendations on their segregation.

Though the majority of drycleaner sites observed during NICNAS visits are unlikely to store more than the 1000 litres of tetrachloroethylene referred to above, it is conceivable that large “factory type” operations could. The *Protection of the Environment Operations Act 1997* provides that drycleaners are not considered waste activities and hence do not require a license to carry on the activity of drycleaning.

10.5 Public health regulatory controls

Tetrachloroethylene is listed in Schedule 5 and Schedule 6 of the Standard for the Uniform Scheduling of Drugs and Poisons.

The entries read:

Schedule 5

TETRACHLOROETHYLENE in preparations containing 5 per cent or less tetrachloroethylene **except**:

(a) when prepared for therapeutic use; or

(b) when absorbed into an inert solid.

Schedule 6

TETRACHLOROETHYLENE **except**:

(a) When included in Schedule 5;

(b) in preparations containing 6 per cent or less of tetrachloroethylene when absorbed into an inert solid; or

(c) when prepared for therapeutic use.

First Aid Instructions for tetrachloroethylene read:

- If poisoning occurs, contact a doctor or Poisons Information Centre, Phone Australia 131126.
- If swallowed do NOT induce vomiting. Give a glass of water.
- Avoid giving milk or oils.
- Avoid giving alcohol.
- If skin contact occurs, remove contaminated clothing and wash skin thoroughly.
- Remove from contaminated area. Apply artificial respiration if not breathing.
- If in eyes, hold eyes open, flood with water for at least 15 minutes and see a doctor.

Warning statement and Safety directions for tetrachloroethylene read:

- Vapour is harmful to health on prolonged exposure.
- Forms dangerous gas near radiators or naked flames
- Avoid contact with eyes and skin.
- Avoid breathing vapour or spray mist.
- No smoking.

Any tetrachloroethylene products available for retail sale must bear the above First Aid instructions, Warning Statements and Safety Directions under State Poisons legislation, as well as an appropriate signal heading.

10.6 Environmental regulatory controls

Tetrachloroethylene is on the Australian, Victorian EPA and US EPA air toxics lists. The effect of a chemical being listed under the Australian Air Toxics Program is that monitoring will be undertaken to establish the levels of community exposure. This information will be then be used to determine what national management strategy, if any, should be taken to manage emissions. While not considered a volatile organic compound (VOC) by the US EPA, it is by Australian environmental jurisdictions. Its appearance on the US EPA list is likely to be linked to health concerns noting that tetrachloroethylene is a potential carcinogen.

Additionally, the NPI has ranked tetrachloroethylene with a high environmental hazard rating. This rating was recommended by a technical advisory panel following set criteria. The moderate acute and chronic toxicity to aquatic life and the limited extent for bioaccumulation were sufficient to give a high ranking. Exposure was not considered, and an actual risk assessment was not undertaken.

The NPI is an initiative of Environment Australia designed to provide the community, industry and government with information on the types and amounts of certain chemicals being released to the environment. Under the *National Pollutant Inventory Guide August* 2000, (NPI, 2000) facilities using greater than 10 tonnes of tetrachloroethylene per year must report emissions to the NPI. Drycleaners that employ less than 20 people are specifically exempted from reporting emissions of tetrachloroethylene to the NPI.

Tetrachloroethylene is not an ozone depleting substance (ODS). However, it is one of a number of non-ODS chlorinated solvents presented by Montreal Protocol's expert panels as possible alternatives to n-propyl bromide (the Montreal Protocol Parties are currently considering whether to place controls on the production and consumption of n-propyl bromide). A call for information by NICNAS indicated that n-propyl bromide is not used in Australia. Therefore the use of tetrachloroethylene is unlikely to increase if the use of n-propyl bromide is controlled.

Regulations related to environmental protection are generally considered a State issue. Environmental law and regulations seek to reduce, reuse and recycle waste with a view to minimising emissions, and waste going to landfill. Tetrachloroethylene is controlled generally as a hazardous substance rather than being specifically mentioned in environmental Acts or Regulations.

Tetrachloroethylene is classified under the EC Council Directive 96/54/E6 as R51/53 (Toxic to aquatic organisms. May cause long term adverse effects in the aquatic environment) and S61 (Avoid release to the environment. Refer to special instructions safety data sheets). No Australian legislation has adopted the EC environmental classification system, however the classification is provided in NOHSC *List of Designated Hazardous Substances* (NOHSC, 1999a), for information purposes only.

10.6.1 Regulation in New South Wales

Sites using tetrachloroethylene may generate waste contaminated with the chemical, which must be dealt with, and are liable to suffer accidental spillage of the chemical. Licensing to use the chemical, regulation of waste and spillage is regulated by a number of legislative instruments.

As an example of environmental State regulations relevant to tetrachloroethylene, NSW controls are broadly described here.

In that State there are no specific regulations covering tetrachloroethylene contaminated waste, however waste solvent is considered hazardous. If a site (drycleaner or other activity) generates more than 10 tonnes of hazardous waste, or stores more than 2 tonnes at any time the site will require a waste activity licence from the EPA. In general terms most users of tetrachloroethylene identified by NICNAS are unlikely to need a licence, but must comply with the requirements relating to non-licensed waste activities, which are as follows:

- The waste must be stored in an environmentally safe manner and not come in contact with incompatible waste;
- Non-licensed waste activities are required to ensure that the waste generated on site is transported and disposed of correctly; and

- The waste transporter (called authorised contractors) should hold a current EPA licence if the hazardous load at any time exceeds 200 kg.

Pollution of waters also comes under a number of instruments in New South Wales.

The *Protection of the Environment Operations Act 1997,* prohibits pollution of waters and substances listed in the NOHSC *List of Designated Hazardous Substances* (NOHSC, 1999a) are declared water pollutants. Hence, discharge of tetrachloroethylene and associated contaminated waste to the sewers is also regulated with control vested in the local water authority.

Sydney Water, for example, regulates such discharges under its *Trade Waste Policy and Management Plan*. There is a new proposed policy to set a general level for discharge of all chlorinated hydrocarbons from a commercial or industrial premises of < 2 mg/l. Tetrachloroethylene falls under the general category of chlorinated hydrocarbons and is not specifically referred to in the policy. Drycleaners under the proposed policy are deemed to have approval to discharge trade waste to the sewers provided their machinery is fitted with an approved solvent recovery unit.

Both local council officers and authorised EPA officers have the authority to issue a clean up notice or direction should any site be polluting waters or discharging waste above specified limits.

10.7 Overseas regulatory activity

Overseas, there is a general move to decrease the uses of chlorinated hydrocarbons generally and tetrachloroethylene in particular. Some examples are:

- The European Union in Directive 94/60 is to examine placing restrictions on the marketing to consumers of goods containing tetrachloroethylene

- Canada has in place its Chlorinated Substances Action Plan, which aims to virtually eliminate or significantly reduce the most harmful chlorinated substances from the environment. The Plan seeks to reduce annual tetrachloroethylene emissions from 266124 kg in 1994 to 8200 kg in the year 2000. Metal degreasing has been specifically targeted with reductions of 65% by January 2001 and 85% by 2004, (*Environment Canada, Chlorinated Substances Action Plan, 1994*). Drycleaning is targeted to reduce use of tetrachloroethylene from 5500 tonnes in 1994 to 1600 tonnes in the year 2000, (*Environment Canada, Strategic Options for Management of Tetrachloroethylene in the DryCleaning Sector, 1994*).

11. Drycleaning Institute of Australia Initiatives

A number of industry initiatives have been developed by the Drycleaning Institute of Australia (DIA). Approximately 1 in 3 (33%) drycleaning enterprises are members of the DIA, with membership skewed towards the larger enterprises (DIA, 2000). Given the limited membership of the DIA at this time, the adoption of the following initiatives by the industry as a whole is questionable.

11.1 Industry code of practice

Code of practice for plant in the drycleaning Industry

A Code of Practice for Plant in the Drycleaning Industry has been developed by the Victorian Employers' Chamber of Commerce and Industry (VECCI) for the DIA (DIA, 1996).

The stated purpose of the Code is to provide guidance to employers in the drycleaning industry to enable them to address likely risks to health and safety in relation to plant. The Code contains a brief overview of the legal requirements for plant covered by the *Victoria Occupational Health and Safety (Plant) Regulations*, 1995. The Code describes the hazard management process and sets out guidance with regard to hazard identification and risk assessment, risk control, and maintenance and inspection. Hazard management worksheets for a range of plant, such as for drycleaning machines, are provided to assist in the hazard identification, risk assessment and process control.

Code of practice for the safe handling of perchloroethylene solvent in the drycleaning plants

The Code of Practice for the Safe Handling of Perchloroethylene Solvent in the Drycleaning Plants was also developed in 1996 (DIA, 1996). It consists of requirements for new machinery, modification to existing machines, Code of Practice for Operation of Drycleaning Plants Using Tetrachloroethylene Solvent, Guide to Safe Handling of Tetrachloroethylene Drycleaning Solvent and training program in handling of tetrachloroethylene.

The Code of Practice for Operation of Drycleaning Plants Using Tetrachloroethylene Solvent aims to minimise emissions of tetrachloroethylene from drycleaning equipment by promoting proper maintenance of equipment, procedures for handling of tetrachloroethylene and the application of good work practices. It covers requirements for operation of drycleaning machinery, loading and unloading, door seals, leak detection, water separation, distillation, condensers, pump strainer, tetrachloroethylene handling, spillage, waste disposal and employee training.

The stated purposes of the Guide to Safe Handling of Tetrachloroethylene Drycleaning Solvent are to acquaint owners, managers and employees of drycleaning enterprises using tetrachloroethylene with the essential properties of the chemical. It describes the health hazards, appropriate first aid treatments and how to prevent and control potential hazards.

Safe Handling of Tetrachloroethylene Training Program forms the basis of training for drycleaners provided through the DIA and the State departments of Technical and Further Education (TAFE). It includes an overview of occupational health and safety and environmental regulations, properties of tetrachloroethylene, potential effects of exposure, control measures, operation and maintenance of drycleaning machines, emergency procedures and waste management. The course is open to both members of the DIA and non-members.

11.2 Drycleaning industry regulation standard (DIRS)

Drycleaning Industry Regulation Standard is an industry developed self-regulation standard intended to provide the drycleaning industry with a simple framework to manage their enterprises and to comply with their obligations under various State legislation and regulations. The standard has 12 elements and aims to make it as easy as possible for industry members to demonstrate their compliance with the environmental and occupational health and safety legislation and regulations that regulate their enterprises.

The standard was formally adopted by the National Executive of the Association on February 1998 for national implementation. The standard supports and compliments both existing Codes of Practice and has been established as the basis of self-regulation by the drycleaning industry in Australia.

An associated document ‘How to implement the Australian DIRS’ has been published by DIA with assistance of the Federal Government’s Natural Heritage Trust through the Air Pollution in Major Cities Programme to help industry members in implementing the standard. A policy and procedures manual including registers, records and forms and Drycleaning Industry Regulation Standard Training Program is also available.

11.3 Accreditation

Currently, tetrachloroethylene can be manufactured, transported and disposed of only by properly licensed persons in Australia, but there is no qualification on who it is supplied to. The DIA, in seeking to address this issue, has recently applied to the Australian Competition and Consumer Commission (ACCC) for authorisation for premises and personnel accreditation to provide an ongoing incentive for the implementation of the DIRS across the drycleaning industry.

The stated purposes for introducing a system of accreditation are to ensure that tetrachloroethylene is stored, handled, used and disposed of in accordance with statutory and common law regulations and standards in drycleaning premises as well as all individuals who store, handle and dispose of tetrachloroethylene have received proper training in the principles of safe, effective and legal use of this chemical and drycleaning operations.

The stated strategies for achieving the objectives are by training and accreditation of drycleaning personnel who use tetrachloroethylene and other drycleaning solvents, accreditation of drycleaning premises where tetrachloroethylene and other solvents are used and supply of tetrachloroethylene to only those premises and personnel who are tetrachloroethylene accredited.

It is proposed that the Drycleaning Industry Registration Board (DIRB), a legal entity which is a subsidiary of the DIA, will implement and manage the accreditation program. A list of those premises that are tetrachloroethylene accredited and that have tetrachloroethylene accredited personnel is to be placed on a public website to ensure the transparency of all arrangements. At the time of publication of this report the decision of the ACCC is still awaited.

12. Discussion and Conclusions

This section integrates the findings reported in the previous chapters and discusses their significance for the risk of potential adverse effects on the health and safety of workers or the general public, or on the environment.

12.1 Importation and use

Manufacture of tetrachloroethylene in Australia ceased in 1990, with all domestic requirements now being met by import. During 1995 to 1999, import volumes have fallen from about 4200 tonnes to about 2500 tonnes per year. The drycleaning industry uses approximately 78% of the import volume (1950 tonnes in 1999). The remainder is used in formulating industrial and consumer products for use in the automotive, printing and textile areas plus electric motor and general metal, solvent cleaners. Pure chemical is also used in the coal industry, for film cleaning, in petroleum refineries, and laboratories. Some formulated industrial and consumer products for carpet cleaning and electric motor cleaning containing tetrachloroethylene are also imported, but in small quantities (<0.5 tonnes).

12.2 Hazards

For the purposes of this assessment, the physico-chemical, toxicological and human health effects of tetrachloroethylene were summarised from peer-reviewed hazard assessments by international organisations such as IARC, ATSDR, OECD, and US EPA.

Tetrachloroethylene is a volatile hydrocarbon but one which has no flash point and does not form flammable mixtures in air or oxygen. It requires minor amounts of stabilisers to avoid reactions with metals such as aluminium, iron and zinc. Tetrachloroethylene does not explode, but will decompose under high temperatures to yield phosgene, amongst other decomposition products.

In both laboratory animals and humans, tetrachloroethylene is readily absorbed by inhalation, ingestion and through the skin, inhalation being the most common route of exposure in humans. Its acute toxicity in animals and humans is low following inhalation and ingestion. Tetrachloroethylene causes skin irritation and mild eye irritation. High acute exposure levels cause CNS effects in animals and CNS effects and respiratory irritation in humans. Repeated exposure targets the kidney in rats, and the liver in mice. The lowest NOAEL in rats is 300 ppm. There is some evidence of adverse effects on reproduction in animals exposed to several hundred ppm, but inconclusive data as to this effect in humans.

Tetrachloroethylene induces liver tumours in mice, kidney tumours in male rats and mononuclear cell leukaemia in male and female rats. However, there continues to be international debate as to the relevance of these tumours to humans. In Australia, tetrachloroethylene is included in the *NOHSC List of Designated Hazardous Substances* (NOHSC, 1999a) and is classified as a carcinogen category 3.

12.3 Regulatory controls

The storage, handling and use of tetrachloroethylene are controlled by a number of national standards and codes and corresponding State and Territory legislation.

Tetrachloroethylene is included in the *NOHSC List of Designated Hazardous Chemicals* (NOHSC, 1999a). Under the NOHSC *National Model Regulations for the Control of Workplace Hazardous Substances* (NOHSC, 1994c), suppliers of hazardous substances are required to provide current MSDS to their customers and label the chemicals in accordance with the NOHSC *Code of Practice for the Labelling of Workplace Substances* (NOHSC, 1994a). Employers shall conduct an assessment of the risks to health created by work involving potential exposure to any hazardous substance and, where necessary, ensure that the exposure is either prevented or minimised as far as practicable. The Model Regulations also require employers to provide induction and ongoing training to all employees with the potential for exposure to hazardous substances.

Tetrachloroethylene is included in the NOHSC *Exposure Standards for Atmospheric Contaminants in the Occupational Environment* (NOHSC, 1995). The national exposure standard is 50 ppm (340 mg/m^3) 8-h TWA and 150 ppm STEL.

In addition to the NOHSC Standards described above, tetrachloroethylene is listed in the ADG Code (FORS, 1998) and the SUSDP (Australian Health Ministers' Advisory Council, 1998).

Tetrachloroethylene is not specifically subject to legislative control in the States and Territories. Rather it is regulated by virtue of its inclusion under the national codes discussed above being referenced by the jurisdictions in their own legislation. This means that it is very difficult to identify legislative requirements relevant to tetrachloroethylene, particularly for small businesses such as drycleaners. In the States and Territories, almost all of the national provisions pertaining to tetrachloroethylene have been embodied in legislation relating to either occupational health and safety, drugs and poisons or dangerous goods.

In New South Wales, for example most users of tetrachloroethylene would not require a licence, either because of the quantities of chemical they store, the amount of contaminated waste they produce, or because of specific provisions exempting a particular activity from licensing. Wastewater containing tetrachloroethylene is classified as hazardous waste by most state and territory environmental agencies and by local water authorities and prohibitions exist in most jurisdictions to prevent pollution of waters and sewers. Discharge of hazardous waste into sewers is controlled by local water authorities that set limits on the amount of such materials that can be discharged from a given site.

12.4 Occupational exposure

At the import and distribution stage worker exposure is limited with import being either in sealed drums or in bulk shipping containers. Transfer of bulk shipment is via an enclosed unloading system at the dock and transport of bulk is by dedicated road tanker or by drum after filling. The filling of drums or tankers from bulk supply is a closed system.

Drycleaning is the predominant use of tetrachloroethylene in Australia and the principal method to control exposure is enclosure. The extent of exposure depends on the type of machine in use, with operators of older equipment more likely to be subjected to greater exposures. All drycleaning machines draw tetrachloroethylene for internal use from storage tanks within the machine. Loading of machine storage tanks with tetrachloroethylene is either by emptying containers of chemical through the clothes loading door or by pumping chemical direct to the tanks from a bulk tanker. The method used depends on the individual operators' choice. Exposure also occurs through emptying still waste and cleaning filters. However in current generation machines most of these processes are enclosed. Air monitoring data indicates that the average exposure levels in drycleaners are 10 ppm, which is over an order of magnitude below the lowest NOAEL of 300 ppm identified in a 2-generation reproduction study.

Due to the open nature of the coal flotation test process exhaust ventilation, safe work practices and PPE (including respiratory protection) are the principal means of controlling exposure. Limited air monitoring data indicates that exposure levels can exceed 50 ppm. Therefore it is essential that workers wear respiratory protection equipment.

Activities involving other uses of tetrachloroethylene include formulation of car care products, use as a solvent in chemical maskants, the printing and textile industries, and film production. In these activities, exposure is likely to be low as the chemical is used in enclosed processes. Exposure could be significant if there are system breakdowns (e.g. leaks) and high, short-term exposure can occur during loading of tetrachloroethylene and removal of spent chemical. Tetrachloroethylene is also used in laboratories where exposure is likely to be intermittent. In some situations, such as vapour degreasing, the potential for exposure is unknown.

Car care products are used in aerosol form. It is expected that these products will be used in workshops on an intermittent basis and chronic exposure will be low. However, should the products be used on a more regular and continuous basis, exposures could be of concern.

Exposure resulting from use of formulated products in the textile industry is expected to be low because of intermittent use and low concentrations of chemical in the scouring bath.

The conclusions reached above are similar to those of the SIDS assessment (OECD, 1996). Uses considered in the SIDS assessment and relevant to Australia include drycleaning, recycling of tetrachloroethylene, metal degreasing and laboratory use. For all occupational uses, the conclusion was that there are no grounds for concern for human health in relation to sensory irritation and systemic toxicity. For drycleaning, this conclusion was based on measured (predominantly UK) data indicating that the majority of 8h TWA exposures were below 50 ppm and more than 50% were below 30 ppm. Thus exposures via inhalation were well below the value causing sensory irritation in humans (approx. 100 ppm) and below the value estimated to be a non-irritant concentration (50 ppm). For total body burden (inhalation plus dermal exposure), the estimated exposure were 4-fold lower than the no-effect level for systemic toxicity (NOAEL of 300 ppm in a 2-generation animal study) and 15-fold lower than the level associated with renal toxicity.

12.5 Future trends

Importers of tetrachloroethylene expect the decrease in use seen in Australia in recent years to continue based on improvements in drycleaning machine design, the emergence of newer drycleaning technologies not based on the chemical and uses in areas other than drycleaning switching to alternative products. It is reported that drycleaning machines have almost reached the limit as far as decreasing solvent usage by engineering controls is concerned and that future improvements in machine design are likely to result in small decreases in release of tetrachloroethylene. The trend in the future volumes of the chemical for other uses cannot be predicted. For example in the coal flotation assay, several alternatives to tetrachloroethylene have been tested over a number of years but none have proven satisfactory. There is the possibility that the use of tetrachloroethylene in cold cleaning may increase as a result of the NICNAS recommendation to phase out this type of use for trichloroethylene (NICNAS, 2000).

12.6 Conclusions

12.6.1 Occupational health and safety

For the major use, drycleaning, the process is enclosed and monitoring data indicates that exposures are well below the lowest NOAEL determined in animal studies. While debate on the relevance of animal tumours to humans continues, it is not possible to draw firm conclusions on this issue.

In the only open process in which tetrachloroethylene is used on a regular basis, coal density testing, high exposures are likely. Currently the primary measure to control exposure is respiratory protection, however, other measures (such as better enclosure of the process) should be taken to minimise the release of the chemical.

For the majority of other uses, occupational exposure is likely to be low because the process is enclosed and/or use is intermittent. There is the potential for high, long term exposures if aerosol products are used on a regular basis.

It is concluded that based on the known uses of tetrachloroethylene and the current workplace and regulatory control measures a full occupational (risk) assessment is not considered to be required at this time.

12.6.2 Public health

The public use of tetrachloroethylene is minimal, with only a limited range of products available for retail sale. The controls on labelling under the SUSDP, as well as the information relating to the hazards presented in these label warnings provide information on the hazards associated with the chemical.

The release of tetrachloroethylene from drycleaning machines appears to be decreasing, as the design of the machines improves, and more drycleaning operators upgrade to the newer machines. The lowest NOAEL in the SIDS assessment report was 300 ppm (OECD, 1996). All predicted public exposures associated with drycleaned fabrics, including exposures near drycleaning outlets, exposures in the home from stored drycleaned fabrics, and exposures from wearing drycleaned clothes are expected to be intermittent and significantly lower than this NOAEL. Exposure resulting from the use of products containing tetrachloroethylene by the public are more difficult to estimate, and will depend to a large extent on the amount of ventilation. The exposure is expected to be intermittent, and not likely to lead to problems associated with the chronic inhalation of tetrachloroethylene.

Tetrachloroethylene levels in water are expected to be low, as there is minimal release to groundwater. The main exposure to the public from the environment is therefore expected to be from inhalation. As ambient air levels are expected to be around 0.8 ppb this exposure is not of public health concern.

Overall there does not appear to be a significant risk to the public from interaction with those industrial processes the public would come into contact with (e.g. drycleaning) or based on appropriate use of products containing tetrachloroethylene. Aerosol products however could lead to significant exposure if used inappropriately and contrary to the warnings presented on the labels.

As far as public health risks are concerned there is no need for a full risk assessment considering all the uses of tetrachloroethylene in Australia.

12.6.3 Environment

Tetrachloroethylene is not an ozone depleting substance but it is listed on the National Pollutant Inventory (NPI).

Tetrachloroethylene enters groundwater where it persists. This has been demonstrated, for example, in NSW where tetrachloroethylene has been detected in groundwater as a result of past uses, generally solvent degreasing (NSW EPA, 2001 personal communication). Contaminated sites are assessed and measured according to the National Environment Protection Measure on Assessment of Site Contamination.

Releases to water as a result of current use are expected to be minimal. Environmental exposure to tetrachloroethylene will be, in the main, through the gaseous phase by the chemical in the atmosphere.

The chemical can, however be regarded as slightly to moderately toxic to fish and aquatic invertebrates but highly toxic to some invertebrates depending on their life stage. Based on laboratory experiments tetrachloroethylene seems to be practically non toxic to algae. Based on field experiments however, low concentrations showed strong adverse effects on various algae and invertebrates but due to the paucity of data firm conclusions could not be drawn. Effects of tetrachloroethylene on soil organisms is unclear.

In the EU, the chemical is classified as R51/53 (Toxic to aquatic organisms. May cause long term adverse effects in the aquatic environment) and S61 (Avoid release to the environment. Refer to special instructions safety data sheets).

Release from drycleaning and other industries identified will result in tetrachloroethylene primarily partitioning to the atmosphere with only minor amounts expected to partition to other environmental compartments.

Potential adverse impacts on terrestrial plants where exposed to tetrachloroethylene, have been identified. These adverse impacts are noticeable on the photosynthetic apparatus of higher plants and are considered the result of the herbicidal activity of trichloroacetic acid, one of the breakdown products of tetrachloroethylene.

Chloritic effects were noticeable in leaves following exposure at 1.7 ppb over a period of seven months. Predicted air concentrations from point source releases exceed this concentration suggesting plants surrounding tetrachloroethylene emitting industries may be at risk. Additionally, an estimate of tetrachloroethylene concentration in urban air of 0.8 ppb is approaching the level where adverse impacts may be expected and which falls within measured levels in Australian urban air samples.

Monitoring data on tetrachloroethylene levels in air and surrounding vegetation around industries releasing tetrachloroethylene and urban air would allow a better understanding of the potential for adverse environmental impacts. However, it is noted that use levels of tetrachloroethylene in Australia have been declining over the last few years due to better controls in the drycleaning industry.

Any significant increase in the use of tetrachloroethylene in Australia must be reported to NICNAS under the secondary notification provisions of the Act. Such a notification would lead to a reconsideration of the potential for adverse environmental impacts of tetrachloroethylene.

As a result of past manufacturing, accidental spills and controls on use and emissions that were not as strict as they are today, it could be expected that tetrachloroethylene has migrated to groundwater, and probably remains there. The lack of data therefore on amounts of tetrachloroethylene in aquifers is of concern. Storage of the chemical in unbunded areas and in areas where it could come into contact with other chemicals such as oxidising agents (e.g. hydrogen peroxide in drycleaning establishments) could, in the event of a spill, lead to migration into the soil and watertable, or to chemical reactions which might pose a danger to workers and the public.

Environmental risks seem minimal given the current use pattern coupled with the fact that tetrachloroethylene is not manufactured in Australia. A full environmental risk assessment is not considered necessary at this time.

13. Recommendations

NICNAS does not recommend a full (risk) assessment at this time. Nevertheless, given the findings discussed in the previous section, the following recommendations are made:

Occupational Health and Safety

Recommendation 1: Hazard classification

The EU is currently considering amendments to the classification for tetrachloroethylene. When these are agreed, it is recommended that NOHSC adopt the new classification as soon as possible.

Recommendation 2: Workplace controls

As tetrachloroethylene is considered a carcinogen category 3, all workplaces should continue to remove or reduce exposure to the lowest practicable levels, both by engineering means and the use of personal protective equipment by operators where necessary. In particular, it is recommended that for the following activities, identified in this report as having the potential for high or unknown exposures, the following measures should be undertaken:

- Coal Testing - Efforts should be made to reduce tetrachloroethylene exposure levels, such as by improved exhaust ventilation, more enclosure of the process, or use of airtight containers used for density solutions which should only be opened when in use. Operators should wear personal protective equipment, including respiratory protection.
- Material Safety Data Sheets for industrial aerosol products containing tetrachloroethylene should include a warning against repeated and regular use of the product.
- Vapour degreasing tanks should be appropriately designed to minimise exposure to vapours and aerosols. Australian Standard AS 2661- 1983 provides guidance on tank design.
- Drycleaners, where there is a potential for release of tetrachloroethylene to air and water, should implement appropriate measures such as:
    - regular checking for leaks
    - regular servicing of machines
    - use of carbon absorbers and water separators where possible
    - replacing older machines with newer machines as soon as possible.

All occupational health and safety jurisdictions are recommended to encourage the full use of the hierarchy of controls in all industries using tetrachloroethylene, particularly drycleaning, printing and coal testing.

Recommendation 3: Storage of tetrachloroethylene

The chemical should be stored in a bunded area away from other chemicals that may interact with it. Drycleaning premises in particular should be conscious of other chemicals used in their processes (such as hydrogen peroxide), which could react with tetrachloroethylene giving off dangerous fumes.

Recommendation 4: The environment

Industries using tetrachloroethylene should limit as much as possible release of the chemical to the atmosphere, and the chemical should not be released to drains and waterways. Disposal of tetrachloroethylene should be through a licensed waste contractor.

Recommendation 5: Industry Code of Practice

It is recommended that the Drycleaning Institute of Australia consider the information in this report when updating the industry ‘Code of Practice for Safe Handling of Perchloroethylene Solvent in the Drycleaning Plant’.

Recommendation 6: Dissemination of information

It is recommended that plain English guidance detailing the Occupational, Health and Safety and environmental legal requirements be prepared and widely distributed to users of tetrachloroethylene, particularly small businesses such as drycleaning enterprises. Guidance on plant design and operation, safe chemical use and available sources of information should also be readily available to all users of tetrachloroethylene. This information should be prepared by the State and Territory authorities or industry associations (such as the DIA) or in collaboration.

14. Secondary Notification

Under section 65 of the Act, the secondary notification of tetrachloroethylene may be required where an introducer of the chemical becomes aware of any circumstances that may warrant a reassessment of its hazards and risks. Specific circumstances include:

- the function or use of tetrachloroethylene has increased, or is likely to change, significantly (including the regular use of aerosol products);
- the amount of tetrachloroethylene introduced into Australia has increased, or is likely to increase, significantly;
- manufacture of tetrachloroethylene has begun in Australia; and
- additional information has become available to the introducers as to the adverse health, safety or environmental effects of tetrachloroethylene.

The Director must be notified within 28 days of the person becoming aware of any of the above or other circumstances prescribed under section 65 of the Act.

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