Reducing Health Impacts of Perchloroethylene from Dry Cleaning in Toronto

Technical Report

Dr. David McKeown
Medical Officer of Health

April 2007

Reference: Toronto Public Health, Reducing Health Impacts of Perchloroethylene from Dry Cleaning in Toronto. Toronto, Ontario: April 2007.

Authors: Sudha Sabanadesan and Loren Vanderlinden

Acknowledgements: We thank Ronald Macfarlane and Monica Campbell, Environmental Protection Office, Toronto Public Health for comments and advice essential to the preparation of this report. We also gratefully acknowledge Veronica Cruz and Lorraine Fung of Toronto Public Health for their assistance in collecting information.

Distribution: This report is available at: *http://www.toronto.ca/health/*

For more information: Environmental Protection Office
Toronto Public Health,
277 Victoria Street, 7th Floor
Toronto, Ontario,
Canada M5B 1W2.

Tel: 416-392-6788
Fax: 416-392-7418

Table of Contents

1.0 Introduction

1.1 Background

Commercial dry cleaners are typically concentrated in urban centres. As Toronto's population continues to grow, along with rapid development in the housing and commercial sectors, the dry cleaning industry is expected to expand to keep up with demand. The dry cleaning industry is made up of institutional, retail and industrial operations. In Toronto however, it is predominantly represented by small family-owned operations employing 4 to 6 employees per facility. The main trade associations representing dry cleaners in Toronto are the Korean Drycleaners Association of Canada and the Ontario Fabricare Association. Collectively, membership is not extensive in these associations.

Tetrachloroethylene, also known as perchloroethylene, which is commonly called perc, is the predominant solvent used for dry cleaning in Toronto and the rest of Canada and it has been used widely since the 1960s. Perc is classified as 'toxic' under the *Canadian Environmental Protection Act* (1999) because of its potential to cause harm to the environment. In addition, the International Agency for Research on Cancer (IARC) classifies perc as a probable human carcinogen (IARC, 1995).

Toronto has about 360 dry cleaning facilities using tetrachloroethylene (EC, 2006). Although the exact number is not known, some of these facilities are co-located in buildings with commercial businesses and residential units. Toronto also has professional fabric cleaning operations that employ wet cleaning technology where water is the solvent. Wet cleaning is also known as "green cleaning" in Ontario. Toronto dry cleaners also use hydrocarbon solvents and to a lesser extent, volatile methyl siloxane-based solvents for cleaning fabric.

Ontarians use more tetrachloroethylene per capita than the rest of Canada (EC, 2001). In 2005, an estimated 205 tonnes (205,000 kg) of tetrachloroethylene was purchased for use in dry cleaning in Toronto alone, which accounts for around 40% of the total tetrachloroethylene purchased in Ontario for dry cleaning (EC, 2007).

1.2 Purpose and Scope of this Report

This report summarizes the public health impact of the dry cleaning industry in Toronto. Tetrachloroethylene is the solvent used in most Toronto dry cleaning operations. Therefore this report summarizes the information on human exposure to and the potential adverse health effects from tetrachloroethylene. It also discusses some ways that the City might ensure that the dry cleaning industry reduces the use of harmful chemicals, with a focus on locations where the public is most likely to be exposed. The report considers the cleaning solutions and technologies that are alternatives to perc-based dry cleaning, the emission control legislation applicable in Toronto, and the legislative and "best practice" measures taken by other jurisdictions. In addition, preliminary discussions with some representatives of Toronto's dry cleaning industry helped identify issues relevant to dry cleaning in Toronto for discussion in this report.

2.0 Health Effects of Tetrachloroethylene

The main health effects that are associated with human exposure to perc are carcinogenicity and toxic effects on the central nervous system, kidney, liver, and on reproduction and development (IPCS, 2006). Human data on the effects of perc exposure are mostly from occupational studies involving workers repeatedly exposed to perc and possibly to other solvents, in the dry cleaning, electronics, and metal degreasing industries (IPCS, 2006). Recently, global experts working for the International Programme on Chemical Safety (IPCS) conducted an in-depth assessment of the toxicity and carcinogenicity of perc (IPCS, 2006). The information provided in this section on the health effects due to chronic exposure to perc is largely drawn from this 2006 publication.

2.1 Toxicity

Acute Effects

Short term inhalation of tetrachloroethylene at very high levels (i.e. equal to or greater than $6.78X10^5$ μg/m^3) (CCOHS, 1999) can lead to irritation of the nose and throat and depression of the central nervous system with symptoms such as drowsiness, dizziness, giddiness, headache, nausea, loss of coordination, confusion and unconsciousness. (Appendix 2 lists the tetrachloroethylene air concentrations at which these symptoms occur.) Exposure to very high levels of perc has resulted in death (CCOHS, 1999).

Chronic Effects (Non-cancer)

The central nervous system, liver, kidneys, respiratory system, eyes, and skin are target organs for perc toxicity in humans (WHO, 2000; NIOSH, 2005). Chronic inhalation exposure to perc is associated with headaches, impaired cognitive and motor neurobehavioral functioning, color vision impairment, cardiac arrhythmia, liver damage and adverse effects on the kidneys (CARB, 2006b). Injury to certain regions of the kidney occurs from perc concentrations of 100,000 μg/m^3 in air (IPCS, 2006).

Occupational studies have found neurotoxic effects at a mean exposure level of 83,000 μg/m^3. These neurotoxic effects include disrupted visual function and altered cognitive processing of visual information. The ability to detect visual patterns was significantly reduced in residents and among workers in a day care chronically exposed to high indoor air levels of perc in two New York City apartment buildings that also housed a dry cleaning facility (Schreiber et al., 2002). The residents who participated in this study had a mean exposure of 778 µg/m^3 for an average of 5.8 years, whereas the day care workers had a mean exposure of 2,150 µg/m3 for an average 4 years. (Appendix 4 lists the guideline values set to protect public health from chronic inhalation risk of perc).

Developmental Toxicity

Occupational exposure to perc is associated with adverse reproductive effects such as menstrual disorders, miscarriages, and reduced fertility (USEPA, 2000; CCOHS, 1999). In a retrospective study of women who worked in dry cleaning and laundry facilities, high levels of perc were found to increase the risk for spontaneous abortions (Doyle et al., 1997). Perc in the maternal bloodstream crosses the placental barrier to reach the fetal bloodstream (TPH, 2001). Perc concentrates in breast milk since it is highly fat soluble and long-lived in the human body (Spengler et al., 2001). Breastfeeding infants therefore may be exposed to perc in mother's milk (CCOHS, 1999).

2.2 Carcinogenicity

The International Agency for Research on Cancer (IARC) classifies perc as a probable human carcinogen (IARC, 1995). IARC found evidence for consistently positive associations between exposure to perc and the risks for esophageal and cervical cancers, and for non-Hodgkin's lymphoma in its evaluation of the human cancer studies (IARC, 1995). Higher rates of mortality due to cancer of the esophagus and cervix were found among workers at dry cleaning establishments (IPCS, 2006). Occupational studies suggest also that there was an excess of kidney cancers and non-Hodgkin's lymphoma (IPCS, 2006).

Reports of increased incidence of cancer in humans due to exposure to perc have come mainly from studying dry cleaning and laundry workers. Some scientists however view such occupational studies as providing limited evidence that perc is a human carcinogen (IPCS, 2006). A number of agencies describe the epidemiological evidence as limited because (IARC, 1995: CalEPA, 2005; WHO, 2000; Health Canada, 1995; USEPA, 2000):

- The findings from different studies are not consistent;
- The studies often do not control for other factors that may contribute to higher cancer risks, such as socio-economic status, or exposure to other toxic chemicals used in dry cleaning and laundry operations; and
- Some of the studies have relatively small numbers of subjects.

The evidence in animals is stronger (IARC, 1995; NTP, 1986). Long term (2-year) inhalation studies on mice show an increase in malignant liver cell cancers in males and females, and an increase in benign liver tumours in males (NTP, 1986). Similar studies on rats showed an increase in certain leukemias in both males and females and rare kidney tumours in males (NTP, 1986). The study authors conclude that inhalation of tetrachloroethylene is clearly linked to cancer in mice and in male rats and that there is some evidence of carcinogenicity for female rats as well (NTP, 1986). Most regulatory agencies have used these rodent inhalation studies carried out by the U.S. National Toxicology Program (NTP) as the basis for deriving the cancer potency of tetrachloroethylene in humans. As well, a long-term exposure inhalation study carried out by the Japan Bioassay Research Centre showed dose-related increases in the incidences of benign and malignant liver tumours in mice in both sexes (Nagano et al., 1998 as cited in IPCS, 2006).

The U.S. National Cancer Institute (NCI) conducted an oral exposure study on mice (NTP, 1977). This study indicates a highly significant increased incidence of liver cancer in both male and female mice (NTP, 1977). The NCI oral study and the NTP inhalation studies demonstrate that tetrachloroethylene causes liver cancer in mice. The increased incidence of leukemia and malignant kidney tumours in rats from the NTP inhalation studies is further evidence of the carcinogenic effects of perc in animals.

Agency-Specific Cancer Classifications

Regulatory agencies internationally do not agree in their classification of perc as a human carcinogen. (Table 1 lists agency-specific cancer classifications). At issue is whether the results from rodent inhalation studies are appropriate for assessing cancer effects of perc in humans. Specifically, Health Canada concludes that rodents metabolize tetrachloroethylene by different pathways and therefore animal study results should not be used. This is the reason Health Canada classifies perc as “unlikely to be a human carcinogen”. However, the recent IPCS expert panel asserts that rodent cancer studies are of potential relevance to humans. In their evaluation, the IPCS scientists conclude that there is no convincing evidence that perc-induced tumours in rodents arise via modes of action that are unique in rodents (IPCS, 2006) Toronto Public Health considers perc a probable human carcinogen consistent with the IARC.

Table 1: Agency-specific cancer classification for tetrachloroethylene

Agency	Classification	Comments
Health Canada	Group IV (unlikely to be carcinogenic to humans)	Criteria for classification (Group IV.A): There is no evidence of carcinogenicity in sufficiently powerful and well-designed human epidemiological studies. There is some evidence of carcinogenicity in well-designed and well-conducted carcinogenicity bioassays in animals, but the results are limited. (Evaluated in 1996)
USEPA	Group B/C based on 1986 guidelines (intermediate between a probable and possible human carcinogen)	The USEPA is currently reassessing the potential carcinogenicity of tetrachloroethylene[1]. The cancer classification guidelines have been revised since March 2005.
NTP (U.S. Dept. of Health & Human Services) [2]	Reasonably anticipated to be a human carcinogen	Report on Carcinogens, Eleventh Edition (2005)
IARC (WHO)	Group 2A (probably carcinogenic to humans)	Criteria for classification: there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals[3]. (Evaluated in 1995).

[1]U.S. Environmental Protection Agency, Air Toxics Website: www.epa.gov/ttn/atw/hlthef/tet-ethy.html.
[2]Report on Carcinogens, Eleventh Edition; U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program.
[3]International Agency for Cancer Research, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 63 1995.

3.0 Exposure to Tetrachloroethylene

Tetrachloroethylene does not occur naturally in the environment. It is a manufactured chlorinated solvent found in atmosphere worldwide (TPH, 2001; EC, 2001). Although it is not produced in Canada, it is imported for use in the dry cleaning and the manufacturing industries. (Health Canada, 1998). Perc is a colourless, non-flammable, dense, liquid. It has a sweet, ether-like odour detectable at air concentrations[1] of 6,780 to 33,900 µg/m^3 (ATSDR, Undated; ATSDR, 1997). Perc is a highly volatile, organic compound. It is mainly used as a solvent in the dry cleaning and metal cleaning industry, in finishing and processing textiles,

[1] The following conversion factors for perc in air (at 20^{0}C and 101.3 KPa) have been used in this document: 1ppm = 6.89 mg/m^3, 1 mg/m^3 = 0.145 ppm

in the manufacture of paint removers and printing inks, and in the formulation of adhesives and specialized cleaning fluids (Health Canada, 1998; IPCS, 1987). Dry cleaning and solvent degreasing operations are the most significant sources for tetrachloroethylene releases to the environment in Canada (EC, 2001). The dry cleaning industry uses 75% of the total perc consumed in Canada (EC, 2002). The general population is exposed to trace levels of tetrachloroethylene in ambient air, food, and drinking water from ground water sources (IPCS, 1987).

The most significant route of exposure to humans is through inhalation of perc from air, particularly indoor air. Concentrations of perc are expected to be higher indoors than outdoors in urban areas (CARB, 1991). A 1990 study conducted in Canadian cities found levels of perc in outdoor air to range from 0.2 to 0.5 $\mu g/m^3$ (Health Canada, 1995). Environment Canada data from 2002 to 2005 for Toronto's outdoor air indicate that mean perc levels was 0.34 $\mu g/m^3$ and ranged from a minimum of 0.04 to a maximum of 2.09 $\mu g/m^3$. Perc levels of 2.09 $\mu g/m^3$ are 12 times higher than the health bench mark of 0.169$\mu g/m^3$ set by the California Environmental Protection Agency (CalEPA). Perc levels measured inside homes across Canada (not just in cities) in 1990 averaged 3.55 $\mu g/m^3$ (Health Canada, 1995).

Dry cleaned clothes contain perc residue estimated to be around 99 mg/kg of clothing (CARB, 2006a). When dry-cleaned clothes are brought home, they continue to release (or "off-gas") small amounts of perc contributing to the concentrations in the air inside households. Perc is also found in consumer products such as water repellents, fabric finishers, adhesives wood cleaners, aerosolized cleaners, all of which contribute to indoor air concentrations (MDCH, 2005; OMOE, 2005).

3.1 Tetrachloroethylene Emissions from Dry Cleaning

Perc-based dry cleaning machines are equipped to carry out three main functions: washing, extracting perc from the washed clothes, and drying. Newer machines also have a built-in perc vapour recovery function. Unintentional releases, also known as fugitive emissions, are the main source of perc releases to the environment from dry cleaning operations (OSHA, 2005). During the dry cleaning process discharges to the environment (including fugitive emissions) can happen under several circumstances, including from:

- unloading clothes from the machine before they are completely dry of perc
- cleaning and maintaining equipment (e.g. cleaning lint, raking out still bottoms, changing solvent filter, maintenance of water separator)
- handling and storing perc and wastewater containing perc
- leaks in machines, hoses, valves, and ducts
- pressing freshly dry-cleaned clothes

Environment Canada's efforts to regulate and reduce pollutant releases by the dry cleaning industry focus on requiring improved technology for perc-based machines and on reporting requirements. Newer, more efficient machines reduce fugitive emissions and improve perc recycling in the machine. Although the net consumption of perc by the Canadian dry cleaning industry has decreased with the application of these advanced technologies (EC, 2001) the current requirements are not likely to entirely eliminate emissions of perc from dry cleaning.

The emission control technology incorporated into perc-based dry cleaning equipment has improved through time. The newest generation of machines available in Canada (that is, 5th generation machines) are the most efficient, having improved ability to reduce fugitive emissions of perc over earlier generation machines (Table 1 in Appendix 1 lists details on the improvements through time of different perc-based machines.) Dry cleaners using perc in Canada are required to use machines that are at minimum 3rd generation technology. Third generation machines are equipped to wash and dry clothes in the same machine (dry-to-dry machines). They are closed-loop systems that recover perc vapour from the drying cycle with the use of refrigerated condensers. Machines that are 3rd generation or newer do not directly vent perc to the outside. The useful lifetime of dry-to-dry machines is between 10 to 15 years (ERG, 2005).

Studies by the National Institute for Occupational Safety and Health (NIOSH) in the United States, show that workers operating a third generation machine are exposed to perc at 15-25 ppm (103,350 – 172,250 $\mu g/m^3$) concentration in air [2] (Earnest, 2002). Peak exposure is much higher, at 1000 - 4000 ppm (6,890,000 to 27,560,000 $\mu g/m^3$). Peak exposure occurs during loading and unloading of the machine and during routine maintenance. Fourth and 5th generation machines reduce worker exposure to less than 3 ppm (< 20,670 $\mu g/m^3$) and a peak exposure of 10 - 300 ppm (68,900 – 2,067,000 $\mu g/m^3$).

Perc dry cleaning operations also generate hazardous wastes in the form of old filter cartridges, still bottoms, wastewater, and other contaminated wastes. Although fugitive emissions have been identified as the main source of perc releases to the environment, spills and improper disposal of waste also contribute to total emissions. The City of Toronto has identified the dry cleaning sector as a source of perc discharges to sewers. Toronto Water requires dry cleaners to submit a pollution prevention plan under the authority of the Sewer Use by-law.

3.2 Exposure to Tetrachloroethylene from Dry Cleaners Co-located with a Residence

Co-location of dry cleaning facilities with residences is common in cities, as in Toronto. Perc is a volatile substance that easily vaporises and is released to the air during processing. It can pass through ceilings, walls and vents throughout a building. It can enter adjacent buildings

[2] Fugitive emissions from perc machines were measured as time-weighted-average (TWA) worker exposure, over periods ranging from about 6 to 8 hours.

and may even remain in building materials (USEPA, 1998). It is an air pollutant for which indoor air is the pathway of greatest exposure (TPH, 2002).

People who live in buildings with dry cleaning businesses in the same location have significantly higher levels of exposure to perc (IPCS, 2006). A Dutch study reported by the IPCS in 1984, found that residents living above dry cleaners have five times greater exposure to perc (as measured by perc levels in breath) compared to people living adjacent to the cleaners (IPCS, 1984 as cited in IPCS, 2006). In a 1992 German study, concentrations of perc in the blood of residents living near dry cleaning shops, was dependent on the floor and construction type of the building where they lived and not necessarily on the dry cleaning system itself (Popp et al., 1992 as cited in IPCS, 2006).

Similarly, two studies of perc levels in apartments located above dry cleaners also show that the residents' exposure to perc can be considerable (McDermott et al., 2005; Garetano, 2000). The first of these studies, conducted in New York City after the State implemented strict emission control regulations in 1997, showed that despite the overall decrease in indoor air perc, 79% of the 65 apartments sampled had perc levels much higher than the background levels for the area ($\leq$11 $\mu g/m^3$) with a mean perc level of 34 $\mu g/m^3$ (McDermott et al., 2005). The mean levels of perc found in these apartments are 20–fold above the 1 in 1 million lifetime cancer risk value of 1.724 $\mu g/m^3$ estimated by the USEPA and 200-fold higher than CalEPA's health benchmark for lifetime cancer risk set at 0.169$\mu g/m^3$ (see Appendix 4 for chronic inhalation risk values). High levels of perc, exceeding 1000 $\mu g/m^3$, were found in four of these apartments. The second of these studies (done in New Jersey) also found perc concentrations above 1000 $\mu g/m^3$ in these residences even on days that the dry cleaning facility was not in operation.

The New York City study found significantly higher levels of perc in low-income neighbourhoods. The study researchers propose that a number of factors might contribute to the higher levels of perc in apartments including: poor work practices at the co-located dry cleaning facility, undesirable air flow and ventilation systems in older building in the low-income neighbourhoods, and poor structural conditions in the building which allow perc to migrate to the apartments.

4.0 Legislation to Control Perc Emissions Associated with Dry Cleaning

This section provides a brief summary of the legislative authorities and policies adopted by U.S. jurisdictions and by the Canadian government, as well as the provincial and municipal legislation applicable to Toronto dry cleaners. The regulations on dry cleaning from four U.S. jurisdictions are the most progressive measures taken to protect human health and the environment from perc in North America.

4.1 Laws Applicable to Toronto Dry Cleaners

Dry cleaning operations in Toronto are regulated by federal, provincial and municipal laws. The process of dry cleaning itself is regulated by the federal government under the *Canadian Environmental Protection Act* (CEPA). Municipal and provincial legislation pertain to limiting the release of tetrachloroethylene from dry cleaning facilities.

Federal Government - *Canadian Environmental Protection Act* Regulations

Although Health Canada classifies perc as not likely to be a human carcinogen, Environment Canada classifies perc as "toxic" under CEPA because of its potential for causing harm to the environment. Perc use in dry cleaning is regulated under CEPA in the *Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations (SOR/2003-79)*. These regulations require dry cleaners to reduce perc emissions by:

- minimizing spills,
- controlling fugitive emissions from the machine;
- managing the disposal of waste water generated; and
- employing machines with a specified efficiency rating in using perc.

The regulations also require dry cleaners and importers of perc to document and report the importing, recycling, sale and use of perc. The CEPA regulations also specify the technology permitted, that is, the type of dry cleaning machines that can be used. As of August 1, 2005, (i) all newly installed perc dry cleaning machines must be closed-loop (non-vented) dry-to-dry refrigerated machines that employ, at a minimum, the 3rd generation technology (with primary vapour control) for emission control and (ii) perc can no longer be used in any 2nd generation machines (where the air from the drying cycle is directly vented to the outside) Dry cleaners are also prohibited from using perc in transfer machines (that is, 1st or the oldest generation machines) and in spotting agents, and perc cannot be used in self-serve dry cleaning machines.

Dry cleaners are required to report perc-related activities annually to Environment Canada, as mandated by the CEPA regulations. Environment Canada conducts inspections of dry cleaning facilities to ensure they are in compliance with the regulations

Ontario Ministry of the Environment - *Environmental Protection Act* (EPA) Regulations

The *Dry Cleaners* regulation (Ontario Regulation 323/94) made under the authority of the provincial EPA, requires that facilities using tetrachloroethylene, hydrocarbon solvents, or methyl chloroform, have a full-time person trained in the management of contaminants and wastes in connection with the operation of dry-cleaning equipment. Facilities operating a dry cleaning machine that is directly vented to the outside (i.e. 2nd generation) are required to obtain a Certificate of Approval as required by the EPA (section 9). However, in light of the prohibition of 2nd generation machines by the 2003 CEPA regulations, dry cleaners are no longer allowed to operate machines that vent directly to the outside. The Ministry of Environment also approves and supplies dry cleaners with a Generator Registration Number, under the authority of the EPA regulation *General-Waste Management* (Regulation 347), to ship waste material containing perc.

Toronto By-laws

Dry cleaning operations must comply with City of Toronto by-laws that apply to the operation of a business or commercial operation in the city. Those wishing to open a business involving washing/ironing and the use of washing machines or dryers, are required to apply for a business license from the Municipal Licensing and Standards (MLS) division of the City of Toronto. The use of solvents for dry cleaning however, is currently not in the scope of the Licensing by-law. The Toronto Sewer Use by-law applies to dry cleaning facilities since it limits discharges of perc into sanitary sewers and storm sewers. Dry cleaners are also required to submit a pollution prevention plan to Toronto Water as part of Toronto Water's strategy to control the release of perc into the sewer system.

4.2 Emission Control Legislation in U.S. Jurisdictions

United States Environmental Protection Agency (USEPA)

The USEPA is currently bringing into force updated standards for dry cleaning facilities to reduce perc emissions beyond their 1993 National Emission Standard for Hazardous Air Pollutants (NESHAP). The USEPA based the revised standards for perc use in dry cleaning on their evaluation that perc carcinogenicity is intermediate between a probable and possible human carcinogen. The main requirements in the current standards are (i) a phase-out of perc use in co-residential facilities by 2020, (ii) an enhanced leak detection and repair (LDAR) program, and (iii) and, at minimum, to use a perc machine of the 4th generation technology (not applicable to co-residential facilities).

State of New York

Under New York State's Environmental Conservation Law, *Environmental Codes Rules and Regulations of the State of New York*, Title 6 Chapter III, Part 232, "Perchloroethylene Dry Cleaning Facilities", dry cleaners in New York State:

- are required to post a storefront notice of the use of perc at the facility,
- must enclose dry cleaning equipment in vapour barriers if they are located in mixed-use-commercial or mixed-use-residential buildings and
- must comply with maximum allowable limits for fugitive perc emissions from dry cleaning equipment.

These state-wide regulations also require that all new mixed-use facilities be equipped with, at a minimum, a machine of 4th generation technology (secondary vapour control). In addition, any dry cleaner operating in New York City must also comply with the City's Community-Right-to-Know Law which requires reporting and labeling of chemicals such as tetrachloroethylene.

California

The South Coast Air Quality Management District (AQMD) is the regional government agency responsible for air pollution control in Los Angeles and surrounding region in California. It was the first jurisdiction to implement one of the most health protective policies to prevent perc emissions from dry cleaning. In 2002, South Coast AQMD adopted Rule 1421 - Control of Perchloroethylene Emissions from Dry Cleaning Systems, to gradually phase out perc use in all dry cleaning facilities by 2020. It also prohibits the installation of perc machines in new facilities as of January 2003. Dry cleaners are also required to meet stringent emission control standards in the interim, along with environmental training requirements, record keeping, and reporting of perc usage.

The state of California considers perc a probable human carcinogen. In January 2007, the California Environmental Protection Agency (CalEPA)'s Air Resources Board passed a rule to phase-out perc-based dry cleaning in the state of California by 2023. The regulation requires dry cleaners co-located with residences to phase-out perc machines sooner, by 2010. It also prohibits new installation of perc machines as of January 1, 2008, and requires perc machines 15 years or older to be removed from service by 2010. California is the first state in the U.S. to prohibit the use of perc in dry cleaning.

5.0 Current Practices in Toronto to Reduce Perc Emissions from Dry Cleaning

Perc releases from dry cleaning operations have been reduced significantly by the introduction of emission control mechanisms built into the machines (Earnest, 2002). As described in Appendix 1, the newer machines (namely 3rd to 5th generation machines) have improved features such as drying sensors, carbon adsorption, cycle lock-out, refrigerated condensers and closed-loop systems. These features have led to lower fugitive emissions of perc. Perc demand in Canada declined between 1994 and 2000, driven by a 56% reduction in its use by the dry cleaning industry (EC, 2001). The industry states that this decline is mainly due to improved perc-based dry cleaning technology as reflected in the shift to 3rd or higher generation machines which make more efficient use of perc (EC, 2001). As well, the overall reduction in public demand for dry cleaning attributed to relaxed workplace dress codes explains some of the decrease in perc use. Although technological advances may help limit fugitive emissions from dry cleaning machines, they do not eliminate perc emissions during the cleaning process (as discussed previously in section 3.1). In addition, perc may be released into the air from accidental spills of perc in the workplace and from the small amounts of perc that are off-gassed from dry cleaned clothes.

Toronto dry cleaners have lowered perc discharges to the environment by using closed, direct-couple delivery of perc from the storage tank to the machine, by eliminating the use of perc-based spotting agents (as is required under the CEPA Regulations) and by educating workers in managing wastes resulting from the dry cleaning process. Equipment maintenance is also critical to reducing fugitive perc emissions. For example, a secondary control mechanism such as a carbon adsorber will lose its efficiency to adsorb perc vapours if not cleaned and replaced regularly (ERG, 2005).

Despite advances in emission control technology, the exposure studies discussed earlier show high levels of perc contamination of indoor air in apartments located above dry cleaners, and substantial worker exposure. Importantly, people living in apartments in low income neighbourhoods or buildings of poor construction, are burdened with much higher exposures to perc, well above some U.S. based health-based guidelines, from co-located dry cleaning operations (IPCS, 2006; McDermott et al., 2005).

6.0 Alternative Dry Cleaning Technologies and Other Considerations

This section summarizes the cleaning technologies that use solvents other than perc. It also discusses the role of public awareness and consumer demand for alternative dry cleaning.

6.1 Alternatives to Perc-based Dry Cleaning

Tetrachloroethylene, as mentioned earlier, is the most commonly used dry cleaning solvent in Toronto and in Canada. However, there are a number of alternatives, known as ‘perc-free’ dry cleaning, that do not use tetrachloroethylene. Some ‘perc-free’ dry cleaning technologies, however, are associated with adverse effects on the environment and on human health. In general, dry cleaning machines are designed to operate efficiently using a specified solvent. (Appendix 3 provides descriptions of four popular alternatives to perc-based cleaning – wet cleaning, hydrocarbon solvent, carbon dioxide cleaning, silicone-based cleaning, as well as a list of emerging fabric cleaning technologies. These four alternate professional fabric cleaning technologies are evaluated in this section.)

Description of the cleaning technologies

This review of the cleaning technologies focuses on the known and potential public health impacts from the alternative chemical solvents used to clean fabric. The available literature on the adverse effects of perc-based cleaning is much larger than for any of the alternate cleaning technologies mentioned in this report.

Liquid carbon dioxide is expected to be relatively the least harmful to human health and the environment, among the alternative organic solvents[3] discussed in Appendix 3. Occupational contact exposure to liquid CO_2 may cause irritation to skin and eyes, and frostbite (USEPA, 1998). According to the CalEPA, this technology does not contribute to global warming since the CO_2 used in the process is the by-product of other industrial processes and therefore there is no net increase in CO_2 (CARB, 2006a). The CO_2 used in the cleaning process is a by-product of existing operations such as the production of ethanol by fermentation and the production of anhydrous ammonia (fertilizer) (PPERC, 2002).

Hydrocarbon solvents including propylene glycol (also referred to as Rynex solvent) are volatile organic compounds (VOCs). Acute exposure to propylene glycol ethers by inhalation may result in eye, nose, and throat irritation and headaches (USEPA, 1998). Introduction of even a small number of Rynex dry cleaned clothes into a poorly ventilated apartment results in high levels of glycoethers off-gassing to the indoor air (Glensvig & Mortensen, 2003). The available toxicity data for hydrocarbon solvents are from studies conducted on an old petroleum-based solvent, Stoddard. Human studies show that acute inhalation exposure to this solvent leads to impaired reaction time and short-term memory, and to eye, ear, and throat irritation (USEPA, 1998). Hydrocarbon solvent emissions also contribute to the formation of ground level ozone which is associated with a range of adverse respiratory and cardiovascular health effects and contributes to increased hospitalizations and deaths (TPH, 2004).

The silicone-based solvent, cyclic siloxanes (GreenEarth™), is also known as Silxane D5. Cancer studies show that exposure to Silxane D5 leads to a statistically significant increase in uterine tumours in female rats (USEPA, 2005). The U.S. EPA is evaluating the potential risks to human health and the environment for Silxane D5. California's South Coast AQMD, which provides financial assistance to dry cleaners to purchase 'perc-free' dry cleaning technologies, has discontinued providing grants for GreenEarth™ cleaning systems pending toxicity data for the silicone-based solvent used in the system (SCAQMD, 2005).

[3] The alternative organic solvents presented in Appendix 3 include propylene glycol ether and other hydrocarbon solvents and cyclic siloxanes (GreenEarth™).

Wet Cleaning

Water-based cleaning technology is widely accepted by regulatory agencies as the best alternative to perc-based dry cleaning. Appendix 3 describes in greater detail three types of water-based technologies - wet cleaning, Green Jet®, and cold water cleaning. Wet cleaning uses detergents that help improve the cleaning efficiency of the water. People may be exposed to the detergents mainly by dermal contact. Workers exposed to the substances (surfactants and surfactant aids) in the detergents do not generally show sensitization or allergic reactions; however, some studies suggest that irritation may occur at low exposure concentrations (USEPA, 1998). Environment Canada and the Ontario Ministry of the Environment determined that waste water from wet cleaning met the model Sewer by-law requirements for Ontario (EC, 1995).

Data collected from 1994 to 1995 from the Green Clean project (described in Appendix 3) indicate that wet cleaning is labour intensive but efficient in cleaning most fabrics. Worker experience and industry know-how in handling wet cleaned clothing determine the efficiency of this cleaning method. The Green Clean project also showed that at one wet cleaning facility there were lowered utility costs.

Water-based cleaning technology has advanced in the ten years since the Green Clean project. Some of the problems encountered in wet cleaning, such as shrinkage, are reportedly avoided with newer processes. In California, dry cleaners who switched from perc-based cleaning to wet cleaning were able to maintain their level of service, reduce their operating costs, and avoid dealing with regulatory requirements applicable to other solvent-based cleaning technologies (PPERC, 2002). This assessment also identified training, proper installation of the wet cleaning equipment, and access to demonstration facilities to observe the wet cleaning process, as being important factors for successful transition to professional wet cleaning. Professional cleaners who exclusively use wet cleaning technology in Toronto report that their cleaning efficiency is comparable to that of the perc-based dry cleaning process.

Industry representatives at a 1995 Environment Canada stakeholder consultation on dry cleaning listed economic factors, garment labeling standards, and consumer acceptability with relation to garment finish and appearance, as the three main determinants of the success of wet cleaning in the market. "Dry clean only" labelling by garment manufacturers has been extensive in recent years. Cleaners are less inclined to use wet cleaning on a garment with a "dry-clean-only" label because of liability concerns (EC, 1996).

Industry representatives indicate hydrocarbon solvents are the most commonly used alternatives to perc among dry cleaners in Toronto. Dry cleaners in the South Coast AQMD in California, where perc use is being phased-out, have switched to hydrocarbon solvent cleaning more often than to the other alternatives. The California Air Resources Board (CARB) also reports that hydrocarbon solvent technology is the fastest growing and most commonly used alternative cleaning technology in California (CARB, 2006a). It does not endorse hydrocarbon-based cleaning and provides monetary incentives for perc-based dry cleaners to switch to either CO_2 cleaning or professional wet cleaning. Increased emissions of hydrocarbon solvents will have a negative impact on local air quality since it contributes to the formation of ozone, an air pollutant of considerable concern in Toronto.

In summary, of the cleaning technologies discussed above, liquid CO_2 and water-based technologies have the least impact on human and environmental health. Studies indicate that their cleaning efficiency is largely comparable to perc dry cleaning. Liquid CO_2 cleaning, however, might be out of reach for small family-owned businesses due to the high cost of the machine, which is estimated to be around US $140,000. There are no known liquid CO_2 cleaners in Toronto.

6.2 Public Awareness and Dry Cleaner Education

People's choice of cleaning services for their clothing is an individual decision. The decision to have clothing dry cleaned is likely based largely on the fabric care label instructions. Garment manufacturers do not consider alternative cleaning technologies such as wet cleaning when testing appropriate cleaning methods. They often use the 'dry clean only' label as a precaution (EC, 1996). The use of 'dry-clean-only' labels has been identified by Industry Canada as a barrier to the market penetration of wet cleaning technology (EC, 1996). Cleaners are reluctant to embrace wet cleaning technology because they have concerns about liability should they damage a 'dry clean only'-labelled garment through the wet cleaning process (EC, 1996). Industry representatives identify fabric cleaner know-how as critical to proper wet cleaning of 'dry clean only' labeled clothing. Educating workers in the proper use of the alternate technologies, to achieve results comparable to perc-based dry cleaning, is important in increasing the use of wet cleaning and liquid CO_2 based cleaning.

Customer awareness and demand also play key roles in shifting to greater use of alternatives to perc in dry cleaning. Governments can increase consumer awareness by highlighting the concerns with perc. New York State regulations require perc dry cleaners to post notice that they use perc at their facility along with other information on the potential health effects of perc exposure. Alternately, government programs can help increase consumer awareness of environmentally sound cleaning methods by selectively identifying and promoting these technologies. Initiatives such as these will educate the public on alternative options. Professional fabric cleaners may also feel encouraged to adopt safer cleaning technologies with increasing consumer awareness and demand.

7.0 Conclusions

Perc is the most commonly used solvent for dry cleaning in Toronto. It has been classified as a probable human carcinogen by IARC. Toronto Public Health recognizes perc as a probable human carcinogen. Although emission control technology in the use of perc for dry cleaning has greatly improved in the last two decades, it has not eliminated the potential for inhalation exposure to the public from use in dry cleaning. In particular, residents living in buildings that also house a facility where perc-based dry cleaning occurs are likely to be exposed to higher levels of perc. Due to the chemical properties of perc, people living in buildings with poor construction are more likely to be exposed to higher levels of perc from indoor air when a dry cleaning facility is located in their building.

There are alternate solvents and technologies to perc that are being successfully used by professionals to clean fabrics. Water-based cleaning technologies and liquid carbon dioxide cleaning are two alternate technologies that have the least detrimental effects on human health and the environment. As discussed previously, California has taken legislative measures to eliminate the use of perc in dry cleaning, and the USEPA is phasing-out the use of perc in dry cleaning operations located in residential buildings. The requirements under the dry cleaning regulations introduced by Environment Canada in 2003 are not based on the most stringent measures that can be taken to protect the public from exposure to perc from dry cleaning. Therefore, Toronto Public Health believes that additional measures are needed to ensure that exposure to perc is minimized, especially from perc-based dry cleaning operations that are located in mixed commercial-residential buildings. Toronto Public Health recommends that the Board of Health request the Medical Officer of Health to report to the Board of Health on the feasibility of municipal regulation to phase out the use of perchloroethylene in dry cleaning facilities which are co-located with residential or other sensitive uses. The Board of Health can also encourage the federal government to strengthen its tetrachloroethylene regulations by eliminating the use of perc in dry cleaning in Canada by the earliest date possible and encouraging professional fabric cleaners to replace it with water-based cleaning and other inorganic solvent-based technologies.

References

Agency for Toxic Substances & Disease Registry, (No Date). Medical Management Guidelines for Tetrachloroethylene. Last Update on 01/24/2007. See: http://www.atsdr.cdc.gov/mhmi/mmg18.html

Agency for Toxic Substances & Disease Registry, 1997. ToxFAQ™ for Tetrachloroethylene (PERC). See: http://www.atsdr.cdc.gov/tfacts18.html

California Air Resources Board (CARB), 1991. Proposed Identification of Perchloroethylene as a Toxic Air Contaminant. Prepared by the Staffs of the Air Resources Board and the Department of Health Services.

California Air Resources Board (CARB), 2006a. California Dry Cleaning Industry Technical Assessment Report. Sections II, III, V, VI. See: http://www.arb.ca.gov/toxics/dryclean/draftdrycleantechreport.pdf

California Air Resources Board (CARB), 2006b. Staff Report: Initial Statement of Reasons for the Proposed Amendments to the Control Measure for Perchloroethylene Dry Cleaning Operations.

California Environmental Protection Agency (CalEPA), 2005. Office of Environmental Health Hazard Assessment. "Technical Support Document for Describing Available Cancer Potency Factors." Perchloroethylene CAS No. 127-18-4.

Canadian Centre for Occupational Health and Safety (CCOHS), 1999. OSH Answers website: www.ccohs.ca/oshanswers/chemicals/chem_profiles/tetrachlroethylene/

Earnest, G.S., 2002. A Control Technology Evaluation of State-of-the-Art, Perchloroethylene Dry-cleaning Machines. *Applied Occupational and Environmental Hygiene* 17 (5): 352-359.

Eastern Research Group (ERG), Inc., 2005. Memorandum to U.S. Environmental Protection Agency, OAQPS (C539-03), on Industry Trends of Major and Area Source Dry Cleaners.

Environment Canada (EC), 1995. "Final Report for the Green Clean™ Project". Prepared by Environment Canada Staff and Green Clean Project Participants.

Environment Canada (EC), 1996. Tetrachlorethylene in the dry cleaning sector: report of the stakeholder consultations. Prepared in partnership by Environment Canada and Health Canada for the assessment of substances found toxic in the first Priority Substances List (PSL), pursuant to the Canadian Envrionmental Protection Act (CEPA).

Environment Canada (EC), 2001. A Comprehensive Review of the 1994 to 2000 Perchloroethylene (PERC) Use Pattern in Canada. Prepared by Cheminfo Services Inc.

Environment Canada, 2002. Trichloroethylene and Tetrachloroethylene Solvent Degreaing. See: www.ec.gc.ca/nopp/docs/rpt/degrease/en/summary.cfm

Environment Canada, 2006. Personal Communications. Candace Sellar, 3/9/2006.

Environment Canada, 2007. Personal Communications. Celia Wong, Vancouver. 2/7/2007

Garetano, G., 2000. Factors Influencing Tetrachloroethylene Concentrations in Residences above Dry-Cleaning Establishments. *Archives of Environmental Health* 55(1): 59-68.

Glensvig, D. and P.Mortensen, 2003. Mapping of Chemicals in dry-cleaned textiles from Rynex and hydrocarbon dry-cleaning shops. *Survey of Chemicals in Consumer Products, Survey No.21.* See: http://glwww.mst.dk/chemi/01080000.htm

Hangers Cleaners, (Not Dated). See: http://www.hangerskc.com/ . Retrieved on 04/11/2007.

Health Canada, 1995. Guidelines for Canadian Drinking Water Quality – Supporting Documents, Tetrachloroethylene.

Health Canada, 1998. *Perchloroethylene (Perc)/PCE/Tetrachloroethylene*, Pages 1-4 from The Health and Environment Handbook for Health Professionals.

International Agency for Research on Cancer (IARC), 1995. Tetrachloroethylene (Group 2A) Summary of Data Reported and Evaluation. *Monographs*, Vol. 63 (1995) p.159.

International Programme on Chemical Safety (IPCS), 1987. *Health and Safety Guide No. 10*. Tetrachloroethylene Health and Safety Guide. See INCHEM website: http://www.inchem.org/documents/hsg/hsg/hsg010.htm

International Programme on Chemical Safety (IPCS), 1996. White Spirit (Stoddard Solvent) Health and Safety Guide. See INCHEM website: http://www.inchem.org/documents/hsg/hsg/hsg103.htm

International Programme on Chemical Safety (IPCS), 2006. "Concise International Chemical Assessment Document 68, Tetrachloroethene". Prepared by Peter Watts, Toxicology Advice & Consulting Ltd.

McDermott, M.J. et al., 2005. Tetrachloroethylene (PCE, Perc) Levels in Residential Dry Cleaner Buildings in Diverse Communities in New York City. *Environmental Health Perspectives* 113(10): 1136-1343.

Michigan Department of Community Health (MDCH), 2005. Health Consultation 'Armen cleaners' Dry Cleaners, EPA Facility ID: MIN000508741. Agency for Toxic Substances and Disease Registry.

National Toxicology Program (NTP), 1977. TR-13 Bioassay of Tetrachloroethylene for Possible Carcinogenicity (CAS No. 127-18-4). See: http://ntp.niehs.nih.gov/index.cfm

National Toxicology Program (NTP), 1986. TR-311 Toxicology and Carcinogenesis Studies of Tetrachloroethylene (Perchloroethylene)(CAS No. 127-18-4) in F344/N Rats and $B6C3F_1$ Mice (Inhalation Studies). See: http://ntp.niehs.nih.gov/index.cfm

Ontario Ministry of the Environment (OMOE), 2005. “Ontario Air Standards for Tetrachloroethylene/Perchloroethylene.” Standards Development Branch. See: http://www.ene.gov.on.ca/envision/env_reg/er/documents/2005/airstandards/PA04E0031.pdf

Pollution Prevention Center (No Date). PPC Projects, Garment Care. Retrieved on 4/17/07 from: http://departments.oxy.edu/uepi/ppc/projects.htm

Pollution Prevention Education and Research Center (PPERC) (now known as Pollution Prevention Center), 2002. Commercialization of Professional Wet Cleaning: An Evaluation of the Opportunities and Factors Involved in Switching to a Pollution Prevention Technology in the Garment Care Industry. Prepared by Sinshemier, P., et al., Occidental College. See: http://departments.oxy.edu/uepi/ppc/publications/commercialization.htm

Schreiber, J.S., 2002. Apartment Residents’ and Dry Care Workers’ Exposures to Tetrachloroethylene and Deficits in Visual Contrast Sensitivity. *Environmental Health Perspectives* 110(7): 655 – 664.

South Coast Air Quality Management District (SCAQMD), 2005. Financial Incentive Grant Program To Assist Dry Cleaners To Purchase Non-Perc Alternative Technologies website: http://www.aqmd.gov/business/drycleaninggrantsNEW.htm

Spengler J.D., J.M. Samet, and J.F. McCarthy (Eds.), 2001. *Indoor Air Quality Handbook* (s. 33.15). Toronto: McGraw-Hill.

Toronto Public Health (TPH), 2001. Potential for Exposure to Ten Carcinogens in Toronto’s Environment and Workplaces. Prepared by Pavel Muller, ToxProbe Inc.

Toronto Public Health (TPH), 2002. Ten Key Carcinogens in Toronto Workplaces and Environment: Assessing the Potential for Exposure. TPH, Toronto.

Toronto Public Health (TPH), 2004. Air Pollution Burden of Illness in Toronto. July, 2004. See: http://www.toronto.ca/health/hphe/pubs.htm

U.S. Environmental Protection Agency (USEPA) (No Date), Design for the Environment (DfE) Case Study: Water-Based Cleaning System for Suede and Leather. http://www.epa.gov/dfe/pubs/garment/wbcs/suede.htm (accessed on 3/31/2006).

U.S. Environmental Protection Agency (USEPA), 1998. Cleaner Technologies Assessment: Professional Fabricare Process, Chapter 3. Retrieved from the Design for the Environment (DfE) website: http://www.epa.gov/dfe/pubs/garment/ctsa/

U.S. Environmental Protection Agency (USEPA), 1998. Cleaner Technologies Assessment: Professional Fabricare Process, Chapters 2, 3, 5, 11. Retrieved from the Design for the Environment (DfE) website: http://www.epa.gov/dfe/pubs/garment/ctsa/

U.S. Environmental Protection Agency (USEPA), 1998. Design for the Environment (DfE) Garment and Textile Care Program, Frequently Asked Questions About Dry Cleaning. See: www.epa.gov/dfe/garment/garment.html

U.S. Environmental Protection Agency (USEPA), 1998. Design for the Environment (DfE) "Cleaner Technologies Assessment: Professional Fabricare Process". Executive Summary. http://www.epa.gov/dfe/pubs/garment/ctsa/

U.S. Environmental Protection Agency (USEPA), 1998. Design for the Environment (DfE) "Cleaner Technologies Assessment: Professional Fabricare Process". Chapter 5. http://www.epa.gov/dfe/pubs/garment/ctsa/

U.S. Environmental Protection Agency (USEPA), 2000. Air Toxics Website "Tetrachlorethylene (Perchloroethylene)" Hazard Summary. See: http://www.epa.gov/ttn/atw/hlthef/tet-ethy.html

U.S. Environmental Protection Agency (USEPA), 2005. Siloxane D5 Fact Sheet Siloxane D_5 in Drycleaning Applications. Retrieved from the Design for the Environment (DfE) website: www.epa.gov/dfe/pubs/garment/d5fs2a1.htm

World Health Organization (WHO), 2000. WHO Air Quality Guidelines – Second edition. Chapter 5.13. See: www.euro.who.int/air/activities/20050223_4

Appendix 1

Table 1: Perc-based Dry Cleaning Technology Available in Canada

Use of the term 'primary control', below, is in reference to built-in mechanical control in the machine that condenses perc vapors. 'Secondary control' refers to additional built-in control, which reduces perc concentrations in the air at the end of the drying cycle.

The information on emission control methods and description of the technologies summarized below have been drawn from the Environment Canada report (1996) on a stakeholder consultation on tetrachloroethylene in the dry cleaning sector (EC, 1996) and from the USEPA commissioned report on dry cleaning submitted to the Office of Air Quality Planning and Standards in 2005 (ERG, 2005).

Type of Machine	Description
Ist Generation – *Transfer Machines*	Separate machines are used for washing/extraction and drying. There is extensive exposure to perc during the transfer of damp clothes from the extraction unit to the drying unit. Furthermore, perc-laden air is emitted from the machine to the outside because the air from the drying unit is vented directly without proper control system to capture perc.
2nd Generation – *Dry-to-Dry Vented Machine*	A dry-to-dry machine differs from a 1st generation machine in its feature to allow both the washing and drying steps to be performed in a single unit thereby eliminating emissions that might occur during transfer of damp clothes to the drying unit. The air from the drying cycle is directly vented to the outside. A carbon adsorber can be installed in the machine as a primary control mechanism.
3rd Generation – *Dry-to-Dry Enclosed Machine*	These machines improve on 2nd generation technology by continuously recirculating the drying air within a closed system. A primary control, usually a refrigerated condenser, is used to remove solvent vapour from the recirculated drying air thus reducing perc emissions. These machines can be retrofitted to draw air through a carbon adsorber, a secondary control, which will improve workplace air quality.
4th Generation – *Dry-to-Dry Enclosed Machine with Carbon Adsorber*	This is a modified 3rd generation machine in which a secondary control i.e. a secondary vapour recovery unit, a carbon adsorber, is used to further reduce perc emissions. Most machines have a timed automatic door interlock to prevent the operator from opening the door before the drying cycle is complete. It may also be equipped with an air fan that draws room air into the unit which minimizes worker exposure.
5th Generation - *Dry-to-Dry Enclosed Machine with Carbon Adsorber and perc sensor*	A sensor measures the perc concentration in the unit. The machine door cannot be opened until the perc concentration in the unit is reduced to a set-point. This feature eliminates the likelihood of perc emissions when opening the door before the drying cycle is complete. These machines can be equipped with add-on features such as a hermetically sealed pump to automatically discharge still sludges to an enclosed waste drum, which reduces worker exposure to perc.

Appendix 2

Table 2: Health Effects associated with short-term inhalation exposure to tetrachloroethylene adapted from the Canadian Centre for Occupational Health and Safety's (CCOHS) occupational health and safety resource for tetrachloroethylene (CCOHS, 1999)

Air Level (µg/m³)	**Short-term Health Effects**
689,000 to 1,378,000 (100-200 ppm)	Headaches, drowsiness, and sleepiness after exposure for 5 – 7 hours.
1,378,000 and above (200 ppm and above)	Nose and throat irritation
1,929,200 (280 ppm)	Incoordination after exposure for 2 hours
4,134,000 (600 ppm)	Incoordination after exposure for 10 minutes
6,890,000 (1000 ppm)	Intolerable irritation of the nose and throat
6,890,000 - 10,335,000 (1000-1500 ppm)	Faintness and dizziness during 2 hour exposures
13,780,000 (2000 ppm)	Losing consciousness (feeling like going to collapse) from exposure for less than 10 minutes.

Appendix 3

Wet Cleaning

The use of water as the primary solvent along with detergents to professionally clean garments in specialized machines is referred to as wet cleaning, and popularized as 'Green Cleaning' in Canada. Prior to the introduction of petroleum based solvents in the 1950s, wet cleaning was widely used by professional cleaners. Recent concerns on the toxicity of tetrachloroethylene and hydrocarbon solvents, and regulatory requirements in some jurisdictions in the U.S.A., have renewed interest in modernizing and using the wet cleaning technique for 'dry clean only' garments.

Wet cleaning is accepted by regulatory agencies as the safe alternative to perc-based dry cleaning. The Ontario Ministry of Energy and Environment, now the Ontario Ministry of the Environment (OMOE), and Environment Canada, endorsed wet cleaning as the best alternative technology and initiated the Green Clean Project, in the mid 1990s, in partnership with industry representation, to explore and promote this water-based technology. Federally funded Green Clean depots were set up to study the wet cleaning technology and collect data. Results from the study (EC, 1995), indicate equal customer satisfaction with Green Cleaned and dry cleaned items. Only a very small percent of garments were damaged or unable to have been wet cleaned (EC, 1995). Significant shrinkage with wet cleaned garments was identified as a problem and pressing wet cleaned garments can be labour intensive in comparison to dry cleaned items (EC, 1995). The project also showed that wet cleaning required the use of more natural gas and water but less electricity than dry cleaning, buteffluent discharges met Ontario Sewer By-law requirements. Initial evaluation at one plant indicated that its annual utility and chemical costs for wet cleaning could be as much as half of the costs for dry cleaning (EC, 1995). KSL, a U.S-based wet cleaning facility for suede and leather, reports a thirty five percent reduction in energy consumption (USEPA, Undated).

Environmental and human health risks posed by wet cleaning have been examined by assessing the toxicity of detergents used in the process, specifically, the chemicals in the detergent that are used as surfactants and surfactant aids to reduce the surface tension of water (USEPA, 1998). Detergents are not volatile and thus the route of exposure to humans is mainly dermal contact. There is a lack of data on human health effects from exposure to wet cleaning chemicals. Occupational exposure to surfactants and surfactant aids have not indicated sensitization or allergy, however, some studies have suggested irritant effects at low concentrations (USEPA, 1998). Risk to aquatic life may exist from release of some surfactants, (e.g. lauramide DEA) and surfactant aids (e.g. citric acid/sodium citrate). In addition to detergents, wet cleaning may employ the use of spotting agents, fabric conditioners, sizing products (for garment crispness), and water repellants (CARB, 2006a).

Hydrocarbon Solvent Cleaning

Synthetic hydrocarbon solvents or synthetic petroleum solvents are the most common alternative to perc. The use of hydrocarbon solvents for dry cleaning have increased in the U.S. as stricter regulations pertaining to perc use in dry cleaning have been implemented in some jurisdictions (ERG, 2005). These solvents are sold under trade names such as PureDry®, EcoSolv®, DF-2000™, Shell Sol 140 HT, Hydroclene™, or Soltrol 130™ (CARB, 2006a). Hydrocarbon solvents are volatile. Unlike the older petroleum based solvents, e.g. Stoddard solvent, which were highly combustible and flammable, the new synthetic solvents have a higher flash point and are stable at operating conditions (CARB, 2006a). Compared to perc, these solvents cost less, although initial capital costs are higher. They are odourless and are efficient in removing oil-soluble and insoluble soils from garments.

The available toxicity data for hydrocarbon solvents are generally from studies conducted on Stoddard solvent (USEPA, 1998). There is inconclusive evidence on the carcinogenicity or the ability of hydrocarbon solvents to produce birth defects in laboratory animals. Human studies have shown acute exposure to this solvent, by inhalation, to be neurotoxic, impaired reaction time and short-term memory, and it is an irritant to the eyes, ears and throat. Hydrocarbon solvents are volatile organic compounds that have the potential to contribute to the formation of ground level ozone, an important component of smog. Smog is linked with a wide range of adverse health effects in humans including but not limited to acute and chronic respiratory illnesses, reduced lung function, asthma attacks, stroke, and high blood pressure. Hydrocarbon solvents contribute to smog and global warming (USEPA, 2005).

The U.S. EPA has assessed Stoddard solvents to be toxic to aquatic life based on acute toxicity values of 0.04 mg/L for daphnids and 0.2 mg/L for fish (USEPA, 1998). The World Health Organization has assessed it to be moderately toxic to aquatic organisms but unlikely to pose significant hazards to the environment because of its volatility and low bioavailability (IPCS, 1996).

Propylene Glycol Ether (Rynex Solvent)

Under the brand names 'Rynex' and more recently 'Impress', ethylene glycol solvents can be used instead of hydrocarbon solvents in hydrocarbon based dry cleaning machines. Rynex can be used in most hydrocarbon machines but perc machines have to be converted to use

Rynex. Propylene glycol solvents are volatile organic compounds, however, Rynex is marketed as having low volatility and as being biodegradable (CARB, 2006a). Acute exposure to propylene glycol ethers by inhalation may result in eye, nose and throat irritation and headaches (USEPA, 1998). A Danish study showed that glycloethers are present in all Rynex dry cleaned textiles (Glensvig & Mortensen, 2003). This study also found that introduction of even a small number of Rynex dry cleaned clothes into a poorly ventilated apartment results in high levels of glycoethers off-gassing to the indoor air.

Silicone Based Cleaning

Cyclic Siloxanes (GreenEarth™), also known as Silxane D_5, is a solvent containing 95 percent decamethylcyclopentasiloxane , an odourless, low-volatile liquid, which is highly efficient in cleaning a variety of fabrics. It is also used in personal care products such as cosmetics and shampoos. This technology is new to Canada with only a few dry cleaners reported to be using it. Dry cleaning machines built for use of perc solvent can be converted, at cost, to GreenEarth™. Cancer studies conducted in rodents have shown a statistically significant increase in uterine tumours in female rats (USEPA, 2005). There are a few hundred GreenEarth™ dry cleaners in the U.S. The USEPA has not made a statement on potential risks to human health or the environment for Silxane D_5 but is currently evaluating risks to human health and the environment.

Liquid Carbon Dioxide

This is a cleaning process that uses CO_2 in the liquid state in specialized machines where the liquid CO_2 and detergent are circulated through clothes in a chamber. The system is closed loop, and washing, vapor recovery and drying are all performed in the same unit (CARB, 2006a). At present, this technology is expensive and not considered a complete replacement for perc-based dry cleaning. However, it is expected to gain popularity as a non-toxic alternative to perc-based dry cleaning. A U.S. based dry cleaning franchise, Hangers Cleaners, exclusively uses CO_2 technology at all 13 of its stores across the country (Hangers, Undated). Occupational contact exposure to liquid CO_2 can cause frostbite and may cause irritation to skin and eyes (CARB, 2006a). The CO_2 used in the cleaning process is a by-product of existing operations such as the production of ethanol by fermentation and the production of the anhydrous ammonia (fertilizer) and is not considered to contribute to global warming (PPC, Undated).

Emerging Technologies

Ultrasonic Cleaning Process - this is an aqeous-based ultrasonic washing process that uses high intensity sound waves in a fluid medium to mechanically dissolve and remove contaminants in clothing (USEPA, 1998).

Biotex Solvent – this solvent is still in development. The manufacturer claims it can be used in existing hydrocarbon machines and modified perc machines (USEPA, 1998).

Ozonated Water – this involves washing with ozonated water (supplied by a ozone generator) in a laundry ozone system as advertised by a supplier of ozone generators (Faraday Instruments, 2006).

Appendix 4

Table 3: Guideline Values for the Chronic Inhalation Risk of Perc

Agency	Guideline Value
World Health Organization	Based on adverse kidney effects in employees working in dry cleaning, the guideline value is set at 250 µg/m3 (WHO Air quality guidelines for Europe). Source: Chapter 5 of WHO Air quality guidelines for Europe 2nd Ed., see www.euro.who.int/InformationSources/Publications/Catalogue/20010910_6
Agency for Toxic Substances and Disease Registry (ATSDR)	Chronic-duration inhalation minimal risk level (MRL) of 0.04 ppm (271 µg/m^3) for perc-based on neurological effects in humans. (The MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure). Source: http://www.atsdr.cdc.gov/mrls/index.html
Health Canada	A tolerable limit of 360 µg/m^3 (24-hour averaging time) based on adverse effects on the liver, kidneys and lungs of animals. Source: http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/existsub/hbct-jact/non_carcinogenic-non_cancerogenes_e.html
USEPA	EPA has calculated a provisional inhalation unit risk estimate of 5.8 × 10^{-7} (µg/m^3)$^{-1}$ for cancer. A provisional value is one which has not received Agency-wide review. This is equivalent to a 1 in 1 million excess cancer risk at 1.724 µg/m^3 Source: http://www.epa.gov/ttn/atw/hlthef/tet-ethy.html
California Environmental Protection Agency (CalEPA)	For cancer effects, CalEPA's Office of Environmental Health Hazard Assessment has set the inhalation health benchmark at 0.169µg/m^3. In other words, it is estimated that there is a 1 in 1 million excess cancer risk at 0.169µg/m^3. Source: http://www.oehha.ca.gov/air/hot_spots/may2005tsd.html
Canadian Centre for Occupational Health and Safety (CCOHS)	The American Conference of Governmental Industrial Hygienists (ACGIH) recommended exposure limit for Tetrachloroethylene: Time-Weighted Average (TLV-TWA): 25 ppm Short-Term Exposure Limit (TLV-STEL) : 100 ppm TLV (Threshold Limit Value) basis is critical effect(s) of Irritation and effects on the Central Nervous System. Source: http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/tetrachloroethylene/working_tetra.html