# FINAL REPORT

# COMPARISON OF PROFESSIONAL GARMENT CLEANING PROCESSES

## SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES

**REVISED**
**10-31-18**

# ABBREVIATIONS

**$CO_2$**: carbon dioxide

**NYSDEC**: New York State Department of Environmental Conservation

**NYSDOH**: New York State Department of Health

**OEHHA**: California Office of Environmental Health Hazard Assessment

**Perc**: perchloroethylene

**ppb**: parts per billion

**SCDHS**: Suffolk County Department of Health Services

**SDS**: Safety Data Sheet

**TURI**: Massachusetts Toxics Use Reduction Institute

**$ug/m^{3:}$** micrograms per cubic meter

**ug/kgbw/day**: micrograms per kilogram of bodyweight per day

**US EPA:** US Environmental Protection Agency

**VOC**: volatile organic chemical

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# COMPARISON OF PROCESSES

## EXECUTIVE SUMMARY

This report on professional garment cleaning processes was prepared pursuant to Suffolk County Local Law No. 15-2016, which required the Department of Health Services (SCDHS) to develop a system to categorize solvents and processes used in garment cleaning based on potential effects on human health and the environment. Six processes are reviewed in this report:

- Perchloroethylene (Perc)
- High Flash Point Hydrocarbons
- Wet cleaning
- Siloxane
- Liquid carbon dioxide, and
- Butylal (Dibutoxymethane).

In order to conduct a comparative review, human health and environmental criteria were selected. The selected criteria were considered the most relevant to Suffolk County and to the objectives of the local legislation, which were to increase consumer awareness of dry cleaning chemical use. Other factors, such as cost, effectiveness and occupational safety are important but not the focus of this evaluation.

Perc has been the primary solvent used in the dry cleaning industry since 1960. In Suffolk County, hydrocarbons have also been in common use for some time, though the formulations have changed with higher flash point hydrocarbon mixtures increasing in use. Wet cleaning, and the processes that use siloxane and butylal and the newly approved hydrocarbons have not been used for long periods of time. Such differences in historical use patterns and changes in formulations create challenges when conducting a comparative review.

Perc has been detected in indoor and outdoor air, water, food, as well as animal and human tissue. Though current regulations require closed loop system dry cleaning machines, which reduce the risk of environmental releases of Perc, some potential for releases and exposure remains. The primary routes of exposure to Perc are inhalation of contaminated air, including that which arises from vapor intrusion via soil and groundwater contamination and releases from dry cleaned clothes, and ingestion of contaminated drinking water. Perc has been classified as a likely or probable human carcinogen by several agencies and has been associated with neurotoxicity (cognitive impairment and delayed reaction time) when exposures occur at concentrations that may be encountered by the public in non-occupational settings. Perc is persistent in the environment and classified as a hazardous air pollutant.

Hydrocarbon releases to the air contribute to the formation of ground level ozone, which can cause adverse health effects. There is some evidence of carcinogenicity of some

hydrocarbon mixtures, based on chronic exposure studies in laboratory animals. Potential dermal exposures are noted if clothing is not completely dry when worn, especially if in contact with the skin for prolonged periods of time (e.g., waistbands of clothing). Hydrocarbons are moderately persistent in the environment, biodegradable, and flammable.

Wet cleaning uses water and detergents to clean clothes. Exposure to the solvent (water) used in professional wet cleaning process is not a concern. The Toxic Use Reduction Institute (TURI) concluded in their 2012 assessment of alternatives to Perc in the dry cleaning industry that wet cleaning posed the least potential risk to human health and the environment compared to the other alternatives evaluated. However, wet cleaning is the only professional garment cleaning process that can discharge wastewater directly to a sanitary system on a regular basis. These sanitary systems are often on-site subsurface systems, which discharge to groundwater. In such cases, any ingredients contained in spotting agents and detergents used in the wet cleaning process would be directly discharged leading to potential impacts to groundwater.

Exposure to the public living near garment cleaning establishments using siloxane ($D_5$) was determined by the California Office of Environmental Health Hazard Assessment (OEHHA) not to pose a risk. Several sources identified a potential for siloxane to persist in the body, as well as evidence that siloxane may cause cancer in laboratory animals at high concentrations when exposed via inhalation, though the relevance of this carcinogenicity data to humans is uncertain. Siloxane is not expected to persist in water but is moderately persistent in soil and sediment. Siloxane does have high aquatic toxicity.

Carbon dioxide is a naturally occurring gas and is a byproduct of normal respiration. Under pressure carbon dioxide becomes a liquid, the form in which it is used for professional garment cleaning. Exposure to sufficiently high concentrations of carbon dioxide in the air can impair the ability of the blood to carry oxygen; it is unlikely that carbon dioxide gas releases from garment cleaning would be high enough to pose a risk to the surrounding community. Carbon dioxide is also a greenhouse gas; however, since the carbon dioxide that is used in the dry cleaning process is reported to be generated as a waste product from industrial operations, its use does not result in the release of additional greenhouse gas. If liquid carbon dioxide were to be discharged to the surface, it would vaporize and not pose a threat to the subsurface environment (e.g., groundwater).

The New York State Department of Environmental Conservation (NYSDEC) estimated that outdoor air annual average concentrations, as well as indoor air concentrations in residences co-located with dry cleaners using butylal (SolvonK4) would be very low. Given that butylal is biodegradable, has low solubility in water and a low tendency to bioaccumulate, potential for exposure via drinking water and food such as fish, from use of butylal, as a dry cleaning solvent appears low. Butylal appears to have low acute toxicity but longer-term toxicity data are lacking. Butylal is not expected to be persistent in water or soil and only moderately persistent in sediment.

Consumer choice categories were created based on human health and environmental factors. The categories were color-coded ranging from red, yellow to green representing the least preferable to the most preferable option (see attached figure). Liquid carbon dioxide was placed in the green category based on both human health and environmental factors, as was wet cleaning in those circumstances when the discharge was to a sewer district, a holding tank or NYSDEC permitted on-site discharge. Wet cleaning processes that discharge directly to an on-site subsurface septic system without a NYSDEC permit were placed in the yellow category for environmental factors. SolvonK4 was placed in green for environmental factors and yellow for

human health considerations. Hydrocarbons and siloxane were placed in yellow based on both human health and environmental factors. Perc was placed in the red category based on both human health and environmental factors.

## 1.0: INTRODUCTION

In June of 2016, Suffolk County adopted a local law designed to increase awareness of the chemical solvents that are used in professional garment cleaning. Suffolk County Local Law No. 15-2016 required the SCDHS to develop a system to categorize these chemical solvents and processes based on potential effects on human health and the environment. Five solvents and processes were identified in the local law for initial categorization. These included:

- Perchloroethylene (Perc)
- High Flash Point Hydrocarbons (DF-2000, EcoSolv, Sasol (LPA-142))
- Wet cleaning
- Decamethylcyclopentasiloxane, aka Siloxane, (Green Earth SB-32 and Green Earth GEC-5), and
- Liquid carbon dioxide.

An additional solvent, butylal (dibutoxymethane) with the trade name SolvonK4, was included in this evaluation because, during the course of the review, SCDHS became aware of its use in Suffolk County. Other solvents may be evaluated at a later time as they come into use in Suffolk County.

Several entities have conducted environmental and human health evaluations of professional garment cleaning solvents, including the New York State Departments of Environmental Conservation (NYSDEC) and Health (NYSDOH), California Environmental Protection Agency, US Environmental Protection Agency (US EPA), Massachusetts Toxics Use Reduction Institute (TURI), the City of San Francisco as well as national and international health agencies. When available, these documents and reviews were our primary source of information. Primary literature was reviewed to supplement this information and to fill data gaps.

In order to conduct the evaluation, specific human health and environmental criteria were developed, focusing on those criteria that would be of particular importance to Suffolk County. The criteria placed an emphasis on potential concerns at the consumer and or community level, as opposed to occupational exposures and risk.

This report provides the basis for the SCDHS evaluation and categorization of professional garment cleaning solvents. This evaluation is a qualitative comparison, as opposed to a quantitative risk assessment or ranking of garment cleaning processes. In this report, dry cleaning refers to professional garment cleaning processes that are not water-based, i.e., those cleaning processes that use non-aqueous solvents, such as those that use Perc, siloxanes or high flash point hydrocarbons. Wet cleaning refers to a professional garment cleaning process that uses water as a solvent (US EPA, 1998). Professional garment cleaning is used as a term to include both wet cleaning and dry cleaning processes.

A limitation of this evaluation is that there are differences in the amount of data available for each solvent to support the comparative evaluation. For example, Perc has been used in dry cleaning for decades. Therefore, there is a fair amount of information regarding toxicity and environmental fate of Perc. However, much less information is available for newer solvents, such as SolvonK4. Differences in quantity and quality of data on potential impacts to health and

the environment limit the ability to compare solvents. When appropriate such data gaps are acknowledged in this report.

## 2.0: EVALUATION CRITERIA

### 2.1: Human Health Criteria

Two categories of human health criteria were evaluated; potential for exposure and potential toxicity. Five pathways/routes of exposure were considered; inhalation of contaminated outdoor or indoor air, ingestion of contaminated food occurring as a result of environmental contamination/bioaccumulation, ingestion of contaminated drinking water, and exposure to an infant via presence of the dry cleaning solvent in breast milk. The toxicity data that were considered the most relevant to this evaluation were those that resulted from low dose, chronic exposures, as might be expected to occur in environmental or consumer exposures, as opposed to toxicity data resulting from higher dose exposures. Such toxicological data typically involves effects such as cancer, reproductive and developmental effects, and in some cases (such as exposure to Perc), neurotoxicity. Information was not always available for each criterion when evaluating individual garment cleaning solvents. In the following sections, no information pertaining to a particular criterion is mentioned when no noteworthy information was obtained during our review.

### 2.2: Environmental Criteria

Precise predictions on environmental impacts are not possible because the subsurface environment is very complex. For instance, there is significant variation in soil types in Suffolk County varying in characteristics such as the amount of sand, organic matter, metal content, acidity, etc. All of these soil characteristics influence the behavior of solvents in the subsurface environment. Many of the new dry cleaning solvents/processes are proprietary making it difficult to find detailed information on fate in the environment.

One of the most important environmental criteria is persistence. Persistence is defined as a contaminant's ability to stay in the soil and/or groundwater because of its resistance to degradation. Persistent contaminants are more likely to remain unchanged in the environment and serve as a source of groundwater contamination. Biodegradation is used as a criterion and is dependent upon the metabolic ability of microorganisms to transform or mineralize a contaminant into less harmful, non-hazardous substances. A contaminant that is easily biodegradable will degrade more readily as it travels through the subsurface and will therefore travel shorter distances at lower concentrations. Biodegradation is a key component of persistence but is listed as a separate criterion because of its importance. Solubility is a criterion that is defined as the degree to which the solvent dissolves in water. The solubility of a substance depends on the physical and chemical properties of the solvent as well as on temperature and the pH of the water. The solubility of a solvent influences its ability to move through the vadose zone and reach groundwater and its ability to remain in solution, potentially transporting it well beyond its source. Aquatic toxicity is considered a criterion and is the ability of the solvent to cause adverse effects to marine life.

## 3.0: PROFESSIONAL GARMENT CLEANING PROCESSES

### 3.1: Perchloroethylene (Perc, or PCE)

Also known as tetrachloroethylene, and tetrachloroethene, Perc is a chlorinated solvent that has been used in industry for degreasing metal parts, and as a chemical intermediate. Perc has been used as a dry cleaning solvent since the 1960's (US EPA, 1998). It is a liquid at room temperature but readily evaporates (e.g., volatilizes) into the air. It has been the most common dry cleaning solvent in the United States (US EPA, 1998). Stabilizers may be added to Perc dry cleaning solvents to prevent corrosion (SCRD, 2009).

### 3.2: High Flash Point Hydrocarbons

High flash point hydrocarbons are also frequently used as the solvent in dry cleaning establishments. Prior to the 1950's, Stoddard Solvent was commonly used as a dry cleaning solvent (TURI, 2012). Perc was introduced as a dry cleaning solvent in the 1960's and became the dominant dry cleaning solvent due to fire hazard concerns with Stoddard Solvent (US EPA, 1998). Hydrocarbon solvents currently used in dry cleaning originate from the distillation of crude oil or natural gasoline and consist primarily of saturated hydrocarbons (Ward, 2013). These high flashpoint (when exposed to a flame will ignite at temperatures greater than 140 degrees F) hydrocarbons consist of isoparaffins and cycloparaffins. Petroleum hydrocarbon dry cleaning solvents may use materials that inhibit biodegradation, such as bacteriostats and antimicrobials (SCRD, 2009). Some of the dry cleaning hydrocarbon products currently approved for use in New York State and used in Suffolk County are listed below.

- DF-2000 (CAS# 64742-48-9), ExxonMobil
- EcoSolv (CAS# 68551-17-7), Chevron Philips (note: formulation may have changed to CAS# 68551-19-9 which would necessitate a new review by NYSDEC)
- LPA-142 (CAS# 64742-47-8), Sasol
- DC-142 (CAS# 64742-88-7), Essential Oils (note: recent information indicates that this product is no longer being marketed by Essential Oils and will therefore be removed from NYSDEC list of alternative dry cleaning solvents).

### 3.3: Wet Cleaning

Wet cleaning is a professional garment cleaning process that uses water as the solvent along with detergents and special machines to clean garments (Cal EPA, 2015). Sophisticated computer controlled washers and dryers are used which enable this process to be used for clothing labeled "dry clean only". Spotting agents may be used to remove stains and post treatment tensioning of certain garments may be necessary. Some of the ingredients identified in a review of a sample of wet cleaning material data safety sheets included:

- Pentapotassium triphosphate
- Alcohol ethoxylates
- Alcohols
- Oleic acid
- Glycol ethers
- D-Limonene
- Monoethanolamine
- Benzene sulfonic acids

- Quaternary ammonia
- Trade secrets

It should be noted that some of these ingredients may also be in detergents used in other garment cleaning processes. However, according to the Toxic Use Reduction Institute, they may be used in a higher concentration in wet cleaning (TURI, 2012). Additionally, 1, 4 dioxane can be a contaminant in alcohol ethoxylates. The New York State Pollution Prevention Institute is currently conducting a study in which various wet cleaning products are being sampled and analyzed for 1,4 dioxane.

### 3.4: Decamethylcyclopentasiloxane (Siloxane, $D_5$)

Decamethylcyclopentasiloxane ($D_5$) is a silicone-based solvent with a flash point of 170 degrees Fahrenheit (TURI, 2012). It is an odorless and colorless liquid, which has a low solubility in water. Siloxane has industrial applications as well as uses in consumer goods such as personal care products (Cal EPA, 2007).

### 3.5: Liquid Carbon Dioxide

In this process, the cleaning solvent is carbon dioxide ($CO_2$). When under pressure (700 to 800 psi) $CO_2$ becomes a liquid. This garment cleaning process requires the use of detergents (TURI, 2012).

### 3.6: Butylal (Dibutoxymethane SolvonK4)

Butylal, the cleaning solvent in SolvonK4 is also known as dibutoxymethane butylal. It may contain approximately 0.06% butanol and 0.007% formaldehyde; two degradation products (Ceballos, et al., 2015b). Butylal is a colorless liquid at room temperature with a flash point of 143.6 degrees F (Ceballos et al., 2015a). It is considered a volatile organic chemical (VOC) (Cal EPA, 2015).

## 4.0: HUMAN HEALTH CONSIDERATIONS

### 4.1: Potential for Exposure

#### 4.1.1: Perchloroethylene

According to the International Agency for Research on Cancer (IARC) Perc has been detected in indoor and outdoor air, water, food, as well as animal and human tissue (WHO, 2014). The primary routes of exposure are inhalation of contaminated air, including that which arises from vapor intrusion via soil and groundwater contamination, and ingestion of contaminated drinking water (Guyton et al, 2014).

Air

Since Perc is a volatile organic chemical (VOC), it readily evaporates and becomes a gas. Therefore, it can enter indoor and outdoor air as a result of its use or discharge. This can occur at locations such as industrial facilities, dry cleaners and even homes, which contain dry cleaned clothes. Exposure via inhalation can occur from vented emissions as well as releases that result from opening and closing machines, or leaking equipment (US EPA, 1998). Though New York

State regulations now require closed loop system dry cleaning machines, this does not completely eliminate the potential for fugitive emissions.

Perc has been measured in outdoor air in a few studies in New York State with the 50$^{th}$ percentile concentration (meaning half of the measured concentrations were below and half were above) reported from each study ranging from less than 0.25 micrograms per cubic meter (ug/m$^3$) to 0.52 ug/m$^3$ (NYSDOH, 2013).

The NYSDOH conducted a study in which the indoor air of homes heated with fuel oil was monitored for a wide variety of VOCs. The 50$^{th}$ percentile indoor air Perc concentration was 0.34 ug/m$^3$ and the 95$^{th}$ percentile concentration was 3.9 ug/m$^3$ (NYSDOH, 2013). In an indoor air survey of homes in suburban and rural areas of New Jersey conducted between December 2003 and April 2006, Perc was detected in 23 out of 100 samples, with a 95$^{th}$ percentile concentration of 4.39 ug/m$^3$ (Weisel, et al, 2008).

Perc was measured by the NYSDOH in indoor air in residences co-located with dry cleaners. The 25$^{th}$ percentile ranged from 215.0 to 268.9 ug/ m$^3$. The 75$^{th}$ percentile ranged from 699.5 to 735.3 ug/ m$^3$ (NYSDOH, 2010). US EPA no longer allows new dry cleaners to be installed in residential buildings and by 2020 existing Perc dry cleaners will no longer be able to operate in a residential building (US EPA, 2006).

Perc residues can remain on dry cleaned clothing leading to subsequent exposure (ATSDR, 2014a). In one study, Perc residues were detected **in** dry cleaned clothes at concentrations ranging from 10- 56 nmol/cm$^2$ (Sherlach, et al, 2011). Perc concentrations detected in cleaned clothing depended on the type of fabric (e.g., wool vs silk) and number of washings. Over a 7-day period following dry cleaning, Perc concentrations in fabric samples were found to decrease by approximately 50 percent. Based on these results, the authors of this study estimated that the indoor air in a sealed closet, approximately 3.4 m$^3$ in size containing 10 dry cleaned wool items could have a Perc concentration as high as 240 mg/m$^3$. Similarly, four wool sweaters that were dry cleaned multiple times and placed in a warm car could result in a Perc concentration inside the car as high as 620 mg/m$^3$ assuming all the residual Perc on the sweaters was released into the air. Perc residues on clothing may not only result in an inhalation and dermal exposure to those who wear dry cleaned clothes but may also result in an inhalation exposure to other occupants of the home or building. The US EPA advises that consumers not accept clothing back from a cleaner if it has a strong odor (US EPA, 2016).

Groundwater

Contamination of groundwater has occurred from the use of Perc in dry cleaning processes. Perc has been found in groundwater at Perc dry cleaning sites in Suffolk County at concentrations orders of magnitude higher than the drinking water standard (MCL) of 5 ppb (Rosser, 2018). According to the Suffolk County Comprehensive Water Resources Management Plan, though Perc was not detected in about 92 percent of the supply wells that were sampled between 2009 and 2013, Perc was detected in three times as many wells in 2013 as in 1987 and the average concentration doubled during this same time period. The maximum concentration of Perc detected in public water supplies sampled between 2009 and 2013 was 93 ppb (Suffolk County, 2015). Use of contaminated groundwater for potable purposes can lead to exposure from drinking, as well as bathing and showering or household use such as laundering.

Once in groundwater, Perc may degrade to trichloroethylene (TCE), cis 1, 2 dichloroethylene and vinyl chloride (ATSDR, 2014a). Perc and its degradation products may volatilize (become a gas) and enter the air spaces in soil. If a building is located above a Perc

groundwater plume, soil gas containing Perc and its related degradation products, may rise up and enter the structure through cracks or openings in the foundation, leading to indoor air contamination. Soil vapor intrusion studies conducted during environmental investigations at dry cleaning sites, overseen by the SCDHS, have detected Perc in soil gas and indoor air of structures near dry cleaning sites at levels that require mitigation.

#### 4.1.2: High Flash Point Hydrocarbons

There is a potential for fugitive emissions to be released from dry cleaners that use hydrocarbon solvents. To prevent exposures to the general population living in the vicinity of dry cleaners that use the hydrocarbon solvent DC-142 the NYSDEC recommended the implementation of specific practices, such as using third generation dry-to-dry, closed loop (non-vented) machines with fugitive emissions control or fourth generation secondary control machines (Ward, 2013). In an earlier study, potential inhalation exposures to the general population within 100 to 400 meters from a hydrocarbon dry cleaning facility were modelled. Lifetime average daily concentrations were estimated to range from 0.00004 to 0.002 $mg/m^3$ (US EPA, 1998). Dermal exposure may also occur if clothing is worn before completely dry (ExxonMobil, 2015).

#### 4.1.3: Wet Cleaning

Inhalation exposures are not expected to be a concern since water is the solvent used in this process. This is the only professional garment cleaning process in Suffolk County that discharges directly to a sanitary system. Many areas of Suffolk County are unsewered and therefore, sanitary systems are often on-site septic systems, which discharge directly to groundwater. In such circumstances, any ingredients in products used by wet cleaners could end up in Suffolk County groundwater, a sole source aquifer.

In a series of studies conducted by the Institute for Research and Technical Assistance on behalf of the State of California, trichloroethylene and Perc were detected in wash and rinse liquid from wet cleaning machines. As reported by the authors, concentrations detected were high enough in some cases to classify the rinse water as hazardous waste, making it illegal to discharge to the sewer. Some of the cleaners tested also had a Perc machine and may have pre-washed garments prior to wet cleaning. Subsequent sampling after the Perc machine was removed showed a decrease, though not an absence in Perc and trichloroethylene in the wash water. It appeared that spotting agents were responsible for at least some of the reported detections (Morris and Wolf, 2005). This raises the potential that under some circumstances wet cleaners may use spotting agents not designed for wet cleaning (e.g., chlorinated solvents). This would be a concern especially if the resulting discharge was to an on-site septic system as contaminants could be released to groundwater. A similar study conducted in Illinois analyzed wash and rinse water following the use of wet cleaning detergents and conditioners. Neither trichloroethylene nor Perc were detected, though spotting agents were not tested (Star and Eyring, 2004).

According to the NYSDEC, such a discharge would require a permit. In Massachusetts, discharges from wet cleaning operations must either discharge to a sewer/publicly owned treatment works, a wastewater holding tank or if a permit is obtained, to groundwater, surface water or a septic system (TURI, 2012).

#### 4.1.4: Decamethylcyclopentasiloxane (Siloxane, $D_5$)

The occurrence of cyclosiloxanes such as $D_5$ has been studied in indoor environments. $D_5$ was the predominant cyclosiloxane detected in indoor and outdoor air in a study reported in 2013 (Yucuis et al, 2013). In this study, $D_5$ was detected in the indoor air at the University of Iowa (office and laboratory locations) at a maximum concentration of 56 ug/m$^3$. The use of $D_5$ in personal care products was attributed as the source of the indoor air concentrations. The concentration of $D_5$ in indoor air was reported to correspond in an increasing relationship to the number of occupants of the location where the measurement occurred. Measured outdoor air concentrations were lower than indoor levels but were higher in urban areas. In a Swedish study, $D_5$ was detected in the indoor air of 250 homes at a mean concentration of 9.7 ug/m$^3$ and a maximum concentration of 79.4 ug/m$^3$ (Norden, 2005)

Exposure to the public living near garment cleaning establishments using $D_5$ was determined by the California Office of Environmental Health Hazard Assessment (OEHHA) not to pose a risk (Cal EPA, 2015). OEHHA did note, however, in a 2007 review that $D_5$ had a significant potential to bioaccumulate and would be considered a highly persistent contaminant (Cal EPA, 2007). $D_5$ has been detected in fish; human fat tissue and breast milk (Cal EPA, 2007). In Germany, $D_5$ was detected in fish and eels from the Rhine River at concentrations up to 1 mg/kg and 2.6 mg/kg, respectively (Mait, 2005). Concentrations as high as 4.5 ug/L were detected in human breast milk samples in Sweden (Cal EPA, 2007).

Cyclosiloxanes, including $D_5$, have been detected in a variety of consumer products such as cleaning, personal care and baby products at concentrations greater than 4,000 ug/g (Dodson, et. al., 2012). In 2008, it was reported that approximately 3,000 cosmetic products contained $D_5$ (Environment Canada and Health Canada, 2008). Therefore, other sources may represent a greater source of exposure than garment cleaning.

#### 4.1.5: Liquid Carbon Dioxide

Carbon dioxide is a naturally occurring gas that is a byproduct of combustion and normal respiration of humans and other warm-blooded animals. A gas under atmospheric conditions, carbon dioxide gas is pressurized to form a liquid for garment cleaning. After each cleaning cycle, the liquid carbon dioxide is evacuated from clothes. After filtering the dirt and grease, the carbon dioxide solution is then reused. Releases of liquid carbon dioxide to the environment from garment cleaning would quickly vaporize and readily dissipate, unless released to an enclosed or confined space. Carbon dioxide is also a greenhouse gas, and therefore, any additional generation of carbon dioxide could add to greenhouse gas emissions. However, according to the California EPA, carbon dioxide that is used in the dry cleaning process is generated as a waste product from industrial operations. Therefore, "Although the amount of emissions from dry cleaning processes has not been studied…" the use in professional garment cleaning does not increase the overall amount of carbon dioxide released into the atmosphere (Cal EPA, 2015). Exposure via groundwater is not anticipated, as use in garment cleaning is not expected to lead to groundwater contamination (USEPA, 1999).

#### 4.1.6: Butylal

Butylal, the solvent used in SolvonK4, is volatile and therefore, its use has the potential to lead to inhalation exposures. In 2011, NYSDEC evaluated the potential for air impacts from dry cleaners using butylal. The NYSDEC concluded that outdoor annual average air concentrations, as well as indoor air concentrations in residences co-located with dry cleaners

using butylal, were predicted to be very low (Ward, 2011b). Given that butylal is biodegradable, has low solubility in water and a low tendency to bioaccumulate, potential for exposure via drinking water, and food such as fish, from use of butylal as a dry cleaning solvent appears low (Ward, 2011b).

In a NIOSH study, formaldehyde, a potential breakdown product of butylal, was detected at low levels in the indoor air of a dry cleaner that used SolvonK4, however, the source of the formaldehyde was inconclusive (Ceballos, et al., 2015a).

## 4.2: Toxicity

### 4.2.1: Perchloroethylene

Absorption into the body

Perc can be absorbed into the body via inhalation, ingestion and dermal exposure (NYSDOH, 2013). Exposure from taking a bath in water containing Perc can lead to dermal exposure. Some estimate that the dose that may be received from such dermal exposures is equal to the dose from ingestion of water containing the same concentration (Keifer, 1998, as cited in US EPA, 1998).

Biomonitoring studies conducted in the United States have found that the concentration of Perc in blood samples was lower than the limit of detection in the 50th percentile of the population sampled (CDC, 2017). However, comparatively higher blood levels of Perc were detected in residents who lived in urban and industrial areas compared to rural settings. Also, concentrations of Perc in blood have been found to be higher for those who live near dry cleaning facilities or have recently dry cleaned clothes in their home (CDC, 2016).

Perc has been found in breast milk (NYSDOH, 2013). In an earlier study, breast milk from nursing mothers in Elizabeth-Bayonne New Jersey area had detections of Perc at concentrations of 0.15 to 43 ug/L, resulting in an estimated exposure to an infant of 0.0001 to 0.82 mg/kg/day (Schreiber, 1997 as cited in US EPA, 1998). These detections were consistent with breast milk concentrations that were estimated based on inhalation exposures in women living in residences above dry cleaners (Sheldon et al., 1985, as cited in US EPA, 1998).

Carcinogenicity:

In 2012, the US EPA concluded a lengthy toxicity evaluation of Perc and concluded that it is “likely to be carcinogenic in humans by all routes of exposure” (US EPA, 2012a). This characterization is based on suggestive evidence of carcinogenicity from epidemiologic studies and conclusive evidence that the administration of Perc, either by ingestion or by inhalation to rats and mice, increased tumor incidence (US EPA, 2012a, b).

The International Agency for Research on Cancer (IARC) classifies Perc as “probably carcinogenic to humans, Group 2A,” based on limited evidence in humans and sufficient evidence in animals (WHO, 2014). The National Toxicology Program has listed Perc as “reasonably anticipated to be a human carcinogen” (NTP, 2016) and Perc is listed as a chemical known to the State of California to cause cancer (Cal EPA, 2018).

Occupational studies of dry cleaning workers in the United States and Europe have provided evidence that exposure to Perc is associated with an increased risk of bladder cancer (WHO, 2014; US EPA, 2012b). Epidemiological studies in workers also provide suggestive evidence that exposure to Perc is associated with an increased risk of non-Hodgkin’s lymphoma as well as multiple myeloma (Guyton et al, 2014; US EPA, 2012b). Occupational studies

provide more limited evidence of an association between Perc exposure and other cancers, such as esophageal, kidney, liver, lung, breast and cervical cancers (WHO, 2014; Guyton, et. al., 2014).

Data from studies in laboratory animals also indicate that exposure to Perc can result in an increased incidence of cancer. Liver cancer has been observed in studies in which Perc has been administered both orally and by inhalation to laboratory animals (WHO, 2014; Guyton, et al, 2014; US EPA 2012b). Mononuclear cell leukemia has also been observed in laboratory rats exposed to Perc via inhalation for a duration of two years (WHO, 2014). According to a review by the US EPA, there were no studies available that provided data on potential cancer risks from early life stage exposure (Guyton, et. al., 2014).

Neurotoxicity:

Based on information gained from animal studies as well as studies that evaluated the effects experienced by people exposed occupationally or in residential settings co-located with dry cleaners, the central nervous system is a target organ for toxicity in acute and chronic exposures to Perc. Inhalation of Perc in sufficient amounts can lead to a depression of the central nervous system (CNS) resulting in dizziness, headache, lightheadedness, and lack of coordination. Higher doses can lead to unconscientiousness or death (ATSDR, 2014a). Longer-term chronic inhalation exposures at lower concentrations have been reported to affect behavior and vision, may lead to memory changes, and reduced reaction time (NYSDOH, 2013; ATSDR, 2014a). A NYSDOH study of residential exposure to Perc found subtle impacts on vision in children who lived in homes with Perc at median concentrations of 340 ug/m$^3$ (NYSDOH, 2010). Neurotoxicity appears to be the sensitive endpoint, as such effects have been observed at concentrations lower than those at which other adverse effects have been observed (Guyton, et. al., 2014). Neurotoxicity (cognitive effects and decreased reaction time) is the sensitive endpoint selected by the US EPA in the derivation of the chronic oral reference dose and chronic inhalation reference concentration (US EPA, 2012b). Similar neurotoxicity has been observed in animal studies (Guyton, et. al., 2014).

Other Toxicity

Human and animal studies also provide evidence that Perc exposure has the potential to affect the liver and kidneys, immune and hematological systems, as well as development and reproduction (US EPA, 2012b). Some studies of workers have provided evidence suggestive of an association between long-term exposure to Perc and adverse reproductive effects including an increased risk of spontaneous abortion, sperm disorders, reduced fertility and delayed conception (NYSDOH, 2013). Animal studies provide evidence that exposure to Perc can affect the liver, kidneys, immune and blood systems, as well as development and reproduction (ATSDR, 2014; Guyton, et. al., 2014).

### 4.2.2: High Flash Point Hydrocarbons

Hydrocarbon solvents are mixtures of petroleum distillates, whose composition can vary making definitive determinations regarding toxicity difficult. Hydrocarbon solvents currently approved by the NYSDEC for use in dry cleaning are high flash point, low aromatic solvents (Ward, 2018). Past formulations of refined petroleum hydrocarbon solvents typically had a much higher percentage of aromatic constituents, such as benzene, compared to those hydrocarbon solvents currently used in dry cleaning (Ward, 2013). A 2015 NIOSH evaluation of

DF-2000, which included an evaluation of SolvonK4, noted that since these alternative dry cleaning solvents are not chlorinated hydrocarbons they "… are likely preferable to PERC." However, since complete toxicological data are lacking on these alternatives, it cannot be definitively determined whether they are without risk (Ceballos et al., 2015b).

Repeated skin contact with DF-2000 may cause dryness and at high enough concentrations can be irritating to the eyes, and respiratory system (Ceballos et al., 2015b). The DF-2000 safety data sheet (SDS) cautions that prolonged skin contact with articles of cleaned clothing that are not completely dry (especially elastic waistbands or shoulder pads) may result in skin irritation such as redness, swelling and potentially blistering (ExxonMobil, 2015).

Information was available for Stoddard Solvent IIC (CAS# 64742-88-7), which has the same CAS# as the solvent used in the hydrocarbon dry cleaning product DC-142 and, therefore, would be expected to have similar chemical characteristics. Information provided to NYSDEC by the supplier/manufacturer demonstrated that the content of aromatic constituents in DC-142 was very low (0.1 percent or lower) compared to Stoddard Solvent IIC (Ward, 2018). This difference reflects the difficulty in characterizing toxicity of mixtures of hydrocarbons as even solvents with the same CAS# may vary in chemical composition. However, since specific toxicity information was not available for DC-142 and Stoddard Solvent IIC has the same CAS# as DC-142, toxicity information for Stoddard Solvent IIC is presented below.

Stoddard Solvent IIC can be readily absorbed via inhalation and has a half-life in the body of 46-48 hours (NTP, 2004; Ward, 2013). In a two-year study involving inhalation exposure to Stoddard Solvent IIC, some evidence of carcinogenicity was found based on an increase in adrenal medulla neoplasms in male rats. The study authors further concluded that an increase in liver adenomas in female mice provided equivocal evidence of carcinogenicity (NTP, 2004). It should be noted that the aromatic content reported in the Stoddard Solvent IIC used in the NTP study had a higher percentage of aromatics (0.58 to 0.93 percent) than documentation submitted to the NYSDEC for DC-142 approval (0.1 percent or less) (Ward, 2018). In general, the higher the aromatic content of a hydrocarbon mixture, the greater its carcinogenic potential. The SDS for EcoSolv, one of the other high flash point hydrocarbons used in garment cleaning, indicates that there is limited evidence of carcinogenicity in animal studies (ChevronPhillips, 2014).

Reduced sperm motility was also observed in both male rats and mice after a three-month exposure to Stoddard Solvent IIC in air at concentrations of 550 $mg/m^3$ for rats and 2200 $mg/m^3$ for mice. Stoddard Solvent IIC was not found to be mutagenic in various *in vivo* and *in vitro* assays (NTP, 2004).

According to California EPA, hydrocarbon solvents would be considered volatile organic solvents, which could contribute to the formation of ground level ozone. Ozone is an air pollutant that is associated with health effects including asthma, respiratory irritation and premature death (Cal EPA, 2015).

#### 4.2.3: Wet Cleaning

Though the solvent used in wet cleaning, water, does not have associated toxicity, the wet cleaning process also uses detergent formulations and spotting agents for which there are a wide variety of formulations. As noted in a study by TURI in 2012, which evaluated garment cleaning alternatives, the ingredients in wet cleaning detergents are often the same as those used in other garment cleaning processes, though they may be used in greater percentages for wet cleaning (TURI, 2012). A review of Safety Data Sheets (SDSs) for detergents and spotting agents used in

wet cleaning provided by the New York Pollution Prevention Institute indicated that many of the SDSs for wet cleaning products contain trade secrets and therefore did not provide the identity of specific ingredients. None of the SDSs reported mutagenicity or carcinogenicity concerns (with the exception of ethyl alcohol) or reproductive toxicity. In addition, none were noted to be on the State of California's list of "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity" (Cal EPA, 2018). However, for many of the products it was noted that data were not available for ingredients contained in the formulation. For some products skin and eye irritation were noted.

Some SDSs indicated the use of ethoxylated alcohols, which have been reported to contain 1, 4 dioxane, as a manufacturing contaminant (HERA Project, 2009). 1, 4 Dioxane is a contaminant of emerging concern in Suffolk County groundwater as it has been detected in public as well as private drinking water supply wells (Suffolk County, 2015). Several health agencies consider 1, 4 dioxane as a potential human carcinogen (US EPA, 2017b). The New York State Pollution Prevention Institute recently undertook a study in which samples of wet cleaning products were analyzed for 1,4 dioxane. Results of that study are pending.

The 2012 TURI evaluation urged wet cleaners to be diligent in checking to see if the products they use contain butoxyethanol (TURI, 2012). There is some evidence that exposure to high levels of butoxyethanol may affect the blood and pose a risk of reproductive problems (ATSDR, 1999).

Since past investigations have detected Perc and trichloroethylene in wash and rinse liquid from wet cleaning machines, it is especially important that wet cleaners are diligent in using appropriate products, such as spotting agents (Morris and Wolf, 2005). This would be particularly important for those wet cleaners that discharge to an on-site septic system, whose effluent is eventually released to groundwater, the sole source of drinking water on Long Island.

#### 4.2.4: Decamethylcyclopentasiloxane (GreenEarth, Siloxane, $D_5$)

Several sources identified a potential for siloxane to persist in the body, as well as evidence that siloxane may cause cancer in laboratory animals at high concentrations when exposed via inhalation (Dodson et. al., 2012; Cal EPA, 2015; Cal EPA, 2007). Only a small percentage of $D_5$ that is applied to the skin is absorbed (Environment Canada and Health Canada, 2008). $D_5$ appears to partition to fat tissues and is eliminated via exhalation (Cal EPA, 2007).

$D_5$ was administered orally in a 3-month study in rats. The only effect noted was an increase in liver weight, though it was not determined if this effect was adverse or adaptive (Environment Canada and Health Canada, 2008).

Subchronic toxicity studies indicate that the lung and liver are target organs following inhalation exposures (Cal EPA, 2007).

$D_5$ has been found to be a dopamine agonist (i.e., binds to a dopamine receptor in the body and mimics the action of dopamine). Dopamine is a neurotransmitter that is involved in brain function as well as physiological processes of the body. Dopamine is also a hormone that regulates the release of prolactin from the pituitary gland (Cal EPA, 2007).

California's OEHHA reported that $D_5$ was not found to have estrogenic activity in various assays in which it was tested (Cal EPA, 2007).

Some developmental toxicity was noted in an inhalation study in rats (Cal EPA, 2007). California's OEHHA raised concern that *in utero* exposure to $D_5$ could increase dopamine levels in the developing brain of an unborn child and lead to adverse effects on brain development (Cal EPA, 2007).

In one study, rats were exposed via inhalation to $D_5$ for 6 hours a day, 5 days a week for 24 months. Female rats exposed to the highest concentration (160 ppm) had a statistically significant higher incidence of uterine tumors (US EPA, 2009). There has been some debate on whether the mechanism for the development of these cancers in rats involves $D_5$ dopamine agonist activity in the pituitary gland which could result in decreased prolactin levels leading to a higher uterine estrogen/progesterone ratio. Though such a mode of action could be plausible for the development of uterine tumors in rats, it is not a relevant mode of action in humans. The California OEHHA did not consider the evidence supporting this mode of action for uterine tumors in rats to be conclusive; they concurred it is not a mechanism that would be relevant to humans (Cal EPA, 2007; Siloxane $D_5$ Board of Review, 2011). $D_5$ has not been found to be mutagenic (Environment Canada and Health Canada, 2008). Based on evidence of liver toxicity in laboratory animals, the California OEHHA developed an interim reference exposure level of 700 ug/m$^3$ for $D_5$ (Cal EPA, 2007).

#### 4.2.5: Liquid Carbon Dioxide

When inhaled, carbon dioxide is carried by the blood and has the potential to impair the ability of blood to carry oxygen if concentrations in air are sufficiently high. It is unlikely that concentrations in a community near a liquid carbon dioxide cleaner would be high enough for such impacts to occur.

#### 4.2.6: Butylal

Acute toxicity data indicate that butylal is of low toxicity by the oral and dermal routes of exposure (Ward, 2011b). However, several reports note there is incomplete information available regarding the toxicity of butylal (TURI, 2012; Ceballos, et al., 2015a; Ward, 2011b). According to a NIOSH review, no adverse effects were observed in an inhalation study in rats exposed to 478 ppm of butylal for 13 weeks (Ceballos, et al., 2015b). Studies of subchronic and chronic exposure duration are lacking. Longer-term exposure studies are necessary to fill in chronic toxicity data gaps such as central nervous system and reproductive and developmental effects, as well as other target organ toxicity (TURI, 2012; Ceballos, et al., 2015a). Studies provided by the manufacturer of SolvonK4 suggest that butylal is not a skin sensitizer, nor skin or eye irritant (Ceballos, et al., 2015b). Butylal was not found to be mutagenic in assays using various strains of bacteria (Lambiotte et al., 2011).

### 4.3: Dose Response and Risk Information

#### 4.3.1: Perchloroethylene

The USEPA has developed an inhalation reference concentration (RfC) for Perc. Exposure to air concentrations below the RfC would not be expected to result in adverse non-cancer effects such as neurotoxicity. The US EPA RfC for Perc is 40 ug/m$^3$ (US EPA, 2012b). Similarly, the US EPA has developed a chronic oral reference dose (RfD) for Perc of 6 micrograms per kilogram body weight per day (ug/kgbw/day) (US EPA, 2012b).

The NYSDOH recently re-evaluated Perc and revised the ambient air guideline to 30 ug/m$^3$ (NYSDOH, 2013). This guideline is designed to protect sensitive populations from continuous exposure. It represents an average air level that the NYSDOH recommends not be exceeded. However, the NYSDOH also suggests that reasonable and practical actions be taken

to reduce exposure to Perc when air concentrations are above background levels (NYSDOH, 2013).

Quantitative cancer potency estimates have been developed by US EPA for both the inhalation and oral routes of exposures based on hepatocellular adenomas and carcinomas observed in laboratory mice. Based on the oral cancer potency, a drinking water concentration of 20 ppb is estimated to correspond to a one-in-a-million cancer risk level. An air concentration corresponding to a one-in-a-million cancer risk level based on the inhalation cancer potency is estimated to be 4 ug/m$^3$ (US EPA, 2012b).

Table 1 provides a summary of the reference criteria noted above for Perc.

**Table 1: Perc Criteria Table**

| CRITERIA | INHALATION EXPOSURE | ORAL EXPOSURE | REFERENCE |
|---|---|---|---|
| **RfC (ug/m$^3$)** | 40 | ----- | US EPA, 2012b |
| **RfD (mg/kgbw/day)** | ----- | 6 | US EPA, 2012b |
| **AAG (ug/m$^3$)** | 30 | ----- | NYSDOH, 2013 |
| **1 in a million cancer risk level** | 4 ug/m$^3$ | 20 ppb (drinking water) | US EPA, 2012b |
| **MCL** | ---- | 5 ppb | US EPA, 2018 |

RfC: US EPA reference concentration
RfD: US EPA reference dose
AAG: NYSDOH Ambient Air Guideline
MCL: Maximum Contaminant Level

As noted in section 4.1.1, Perc has been detected in indoor air in residences in New York State with the 95$^{th}$ percentile concentration approaching the 1-in-a-million cancer risk concentration. Similarly, in New Jersey, the 95$^{th}$ percentile concentration was 4.39 ug/m$^3$, just over the 1-in-a-million cancer risk concentration. The indoor air of residences co-located with Perc dry cleaners was much higher (25$^{th}$ percentile range of 215 to 268.9 ug/m$^3$) and exceeded all of the inhalation criteria in Table 1. Perc has been found to be a contaminant in the source water of public water supplies in Suffolk County in excess of the MCL (Suffolk County, 2015). At Perc dry cleaning sites in Suffolk County, Perc has been found in groundwater at concentrations orders of magnitude higher than both the drinking water standard (MCL) and the 1-in-a-million cancer risk level. Soil vapor intrusion investigations near dry cleaning sites have detected elevated levels of Perc in soil gas and indoor air and lead to the requirement that mitigation be performed.

### 4.3.2: High Flash Point Hydrocarbons

In 1998, the US EPA conducted an evaluation under hypothetical exposure scenarios to the general population. Based on this non-cancer risk evaluation, they concluded that there was a low level of concern for health risks from inhalation exposures to hydrocarbon solvents used in dry cleaning processes, even under modelled worst-case conditions (US EPA, 1998).

In a recent NIOSH report which evaluated the hydrocarbon product DF-2000, the authors concluded that since the solvents used in this product are not chlorinated solvents, the product is likely preferable to Perc. However, they noted that there was not enough information to make a definitive determination (Ceballos et. al., 2015b).

#### 4.3.3: Wet Cleaning

In an evaluation conducted by the US EPA in 1998, potential dermal and oral exposures and related risks were expected to be negligible (US EPA, 1998).

#### 4.3.4: Liquid Carbon Dioxide

Health risks to the general public would not be expected from the use of liquid carbon dioxide for professional garment cleaning processes. Though it is a greenhouse gas, the carbon dioxide that is used in this process is reported to be a by-product of industrial emissions, and therefore, its use does not contribute additional greenhouse gas emissions (Cal EPA, 2015).

#### 4.3.5: Decamethylcyclopentasiloxane (GreenEarth, Siloxane, $D_5$)

Based upon a review conducted in 2007, the California OEHHA concluded that they could not find that $D_5$ was a "non-toxic" alternative to Perc (Cal EPA, 2007). Based on evidence of liver toxicity in laboratory animals, the California OEHHA developed an interim reference exposure level of 700 ug/m$^3$ for $D_5$ (Cal EPA, 2007).

A review conducted by Environment Canada and Health Canada in 2008 concluded that the available information does not indicate that $D_5$ is entering the environment in an amount that would constitute a danger to human life or health (Environment Canada and Health Canada, 2008).

#### 4.3.6: Butylal (SolvonK4)

The NYSDEC concluded in their evaluation of butylal that though toxicological data were limited, all indications were that its toxicity was low (Ward, 2011). In addition, butylal does not appear to be persistent in air, water or soil, or bioaccumulative in the food chain. Therefore, evidence suggests that risks to consumers and the community would be low. However, there are a number of limitations in the conclusion, primarily the lack of long-term chronic exposure data.

According to a recent NIOSH report, since the solvent used in SolvonK4 (butylal) was not a chlorinated solvent it was likely preferable to Perc. However, the authors noted that there was not enough information to make a definitive determination (Ceballos et. al., 2015b).

## 5.0: ENVIRONMENTAL IMPACT CONSIDERATIONS

To supplement and support available resources and literature about the potential environmental impact of the identified garment cleaning solvents if released into the environment, two resources were also reviewed; the US EPA "PBT Profiler" and "Scorecard." A description of these resources is provided below. Please refer to the appendix for further information on specific terms used in these tools. After completion of this garment cleaning review, it was noted that the "PBT Profiler" was no longer available online. As this source was

used to supplement and support information from other sources, the information obtained from the PBT Profiler was retained in this report.

**PBT Profiler** predicts risk related data (physical/chemical properties, bioconcentration, environmental fate, toxicity to aquatic organisms, and other information) on chemicals lacking experimental data. It uses computer-based tools to help identify chemicals that potentially may persist, bioaccumulate, and be toxic to aquatic life, i.e., PBT chemicals.

**Scorecard** is a pollution information website that contains chemical profiles and health hazard information. Scorecard provides comparative assessments of chemicals for various risk categories. For this project, the Environmental Hazard and Ecological Risk categories were reviewed. Those chemicals that have been assessed in Scorecard are ranked from Least Hazardous, which is represented by a score of 0% to Most Hazardous, which is represented by a score of 100% (Good Guide, 2011).

### 5.1: Perchloroethylene

Perc is a dense non-aqueous phase liquid (DNAPL). A DNAPL is denser than and immiscible in water. In the presence of water, it will form a separate layer below the water layer. The half-life in groundwater is estimated to be between 1 to 2 years, but may be considerably longer under certain conditions (California Department of Public Health, 2009). Perc is readily found in the environment due to its widespread use and persistence in water, soil, sediment and air. Bioaccumulation in aquatic organisms is estimated to be low. The aquatic toxicity is considered moderate (TURI, 2012). Perc is expected to biodegrade slowly in water and in soils. Aerobic biodegradation in water takes months, as does anaerobic biodegradation in soil. Hydrolysis in water is estimated to take years. Actual biodegradation rates will depend upon local soil conditions. Perc is a common groundwater contaminant (USEPA, 1998). Perc is volatile and is classified as a hazardous air pollutant (US EPA, 2017a).

Perc has been identified as one of three of the most commonly detected VOCs in Suffolk County groundwater (Suffolk County, 2015). According to a review that was conducted in 2015, Perc has been detected at 10 of 25 federal Superfund sites on Long Island (Fiteni, 2015).

PBT Profiler estimates (US EPA, 2016b):

- Persistence: high potential to persist in water, soil and sediment
- Solubility: low but higher than hydrocarbons
- Vapor Pressure: high, indicating it is a VOC
- Potential to leach to groundwater
- Half-life in Water: 60 days
- Bioconcentration Factor (BCF): estimated to be 81, indicating low potential to bioconcentrate
- Potential chronic toxicity to fish

Scorecard Ranking (Good Guide, 2011):

- Environmental Hazard Value: 100% (most hazardous ranking)
- Ecological Risk Screening: 50% to 75% (100% being the most hazardous)

### 5.2: High Flash Point Hydrocarbons

Hydrocarbons are a complex mixture of individual chemicals. Specific ingredients in the hydrocarbon solvent SDSs used in garment cleaning were sometimes confidential, or referred to as a chemical class or family. Assessments are frequently based on the main constituents of common products. Two specific hydrocarbon solvents, ExxonMobil DF-2000 and Chevron Phillips EcoSolv, were used as references since they are the most widely used at this time in Suffolk County.

High flash point hydrocarbon solvents used in garment cleaning are moderately persistent in sediment and have low solubility in water. The SDSs indicate they are not expected to pose an acute toxicity concern to aquatic organisms, but may have the potential for chronic aquatic toxicity. High flash point hydrocarbons are expected to be biodegradable (ExxonMobil, 2015 and Chevron Phillips, 2014). Migration of high flash point hydrocarbons to groundwater is expected to be negligible (US EPA, 1998). Petroleum garment cleaning emissions are classified as volatile organic compounds (Sinsheimer, et al., 2007).

PBT Profiler estimates (US EPA, 2016b): In order to characterize the hydrocarbon solvents, PBT profiler used a specific chemical structure to represent the hydrocarbon mixture (e.g., Ecosolv (CAS# 68551-17-7)). Because of this, it cautioned the use of the profile results, as it is unknown how well the chemical structure used reflects the characteristics of the hydrocarbon mixture.

- Persistence: low potential to persist in water and soil and high potential to persist in sediment
- Solubility: very low
- Vapor Pressure: high, though lower than Perc
- Potential to leach to groundwater
- Half-life in Water: 15 days
- Bioconcentration Factor (BCF): estimated to be 1200, indicating potential to bioconcentrate
- Potential chronic toxicity to fish

Scorecard Ranking (Good Guide, 2011):

- Not ranked

### 5.3: Wet Cleaning

Wet cleaning detergent formulations are complex mixtures typically containing water and a variety of other different chemicals. As noted in the TURI 2012 evaluation of alternatives to Perc, the ingredients in the detergents used in wet cleaning are often the same as those used in other garment cleaning processes, though they may be used in greater percentages for wet cleaning (TURI, 2012). Some of the SDSs for wet cleaning products indicate that the formulations contain trade secrets and that there is insufficient information regarding ecological effects. A few SDSs indicated moderate aquatic toxicity (Adco Professional Products LLC, 2015) to “toxic to aquatic life with long lasting effects” (Kleerwite Chemical, 2015) for components in the formulations. Most indicated the components were expected to be biodegradable. Some SDSs indicate the use of ethoxylated alcohols which have been reported to contain 1,4 dioxane as a manufacturing contaminant (HERA Project, 2009). 1,4 Dioxane is a

contaminant of emerging concern in Suffolk County groundwater and has been detected in public as well as private drinking water supply wells at levels above a concern (Suffolk County, 2015). The New York State Pollution Prevention Institute recently undertook a study in which samples of wet cleaning products were analyzed for 1,4 dioxane. Results of that study are pending.

As mentioned previously, in a series of studies conducted by the Institute for Research and Technical Assistance on behalf of the State of California, trichloroethylene and Perc were detected in wash and rinse liquid from wet cleaning machines. As reported by the authors, concentrations detected were high enough in some cases to classify the rinse water as hazardous waste, making it illegal to discharge to the sewer (Morris and Wolf, 2005). A similar study conducted in Illinois did not detect trichloroethylene or Perc in wash and rinse water following the use of wet cleaning detergents and conditioners (Star and Eyring, 2004).

Wet cleaning is the only professional garment cleaning process that involves routine discharges to either sewers or a sanitary system. The potential for inadvertent misuse of chlorinated products (e.g., spotting agents) and potential presence of 1, 4 dioxane in wet cleaning products raise concerns related to on-site septic discharges. In Suffolk County, most wet cleaners currently discharge their wastewater to an on-site septic system (SCDHS, 2018). According to the NYSDEC, such a discharge would require a permit. In Massachusetts, discharges from wet cleaning operations must either discharge to a sewer/publicly owned treatment works, a wastewater holding tank or if a permit is obtained, to groundwater, surface water or a septic system (TURI, 2012).

### 5.4: Decamethylcyclopentasiloxane (GreenEarth, Siloxane, $D_5$)

At ambient temperature, $D_5$ is an odorless and colorless liquid. Siloxanes, including $D_5$, possess characteristics of both organic compounds and silicates. Their properties arise from the unique chemistry of the Si–O bond and the influences of the organic substituents (methyl group in this case) at the silica atom, which result in unusual properties related to its organic-silicate hybrid nature. It has relatively low solubility in water, and relatively long half-life in sediments (MacKay et al., 2015). Siloxane is persistent in sediment and air, and moderately persistent in soil. It is moderately bioaccumulative and has high aquatic toxicity (TURI, 2012). Environment Canada stated that the probability of $D_5$ biodegrading in water or soil is "essentially zero" (Environment Canada and Health Canada, 2008).

PBT Profiler estimates (US EPA, 2016b): The CAS# for cyclosiloxanes, a mixture, was used for the PBT Profiler estimates. PBT Profiler used a specific chemical structure to represent the cyclosiloxane mixture. Because of this, it cautioned the use of the profile results, as it is unknown how well the chemical structure used reflects the characteristics of the siloxane mixture.

- Persistence: low potential to persist in water, and moderate to high that it will persist in soil and sediment, respectively
- Solubility: low
- Vapor Pressure: high
- Potential to leach to groundwater
- Half-life in Water: 38 days
- Bioconcentration Factor (BCF): estimated to be 2500, indicating it is a bioconcentration concern

- Potential chronic toxicity to fish

Scorecard Ranking (Good Guide, 2011):

- Environmental Hazard Value: no information
- Ecological Risk Screening: 50% to 75% (100% being the most hazardous)

**5.5: Liquid Carbon Dioxide**

Though it is a greenhouse gas, the carbon dioxide that is used in this process is reported to be a by-product of industrial emissions, and therefore, its use does not contribute additional greenhouse gas emissions (TURI, 2012 and Cal EPA, 2015).

The Solvair system, a carbon dioxide system that uses propylene glycol ether as a solvent is not addressed in this document since it is not currently used in Suffolk County.

Because liquefied carbon dioxide under high pressure will readily evaporate if there is any leak in the machine, it is unlikely that a carbon dioxide release would result in soil or water contamination. Carbon dioxide is not persistent in soil, and is a natural component of our atmosphere (TURI, 2012).

PBT Profiler estimates (US EPA, 2016b):

- Persistence: low potential to persist in water, soil and sediment
- Solubility: low but higher than hydrocarbons
- Vapor Pressure: high, is a gas at room temperature
- Potential to leach to groundwater
- Half-life in Water: 60 days
- Bioconcentration Factor (BCF): estimated to be 3.2, indicating it is not expected to bioconcentrate
- Chronic toxicity to fish not expected

Scorecard Ranking (Good Guide, 2011):

- Environmental Hazard Value: 0% (least hazardous ranking)
- Ecological Risk Screening: not ranked

**5.6: Butylal**

Butylal comprises >99% of the dry cleaning product SolvonK4. Based on its low solubility in water, biodegradability, and low toxicity, butylal is not expected to cause acute aquatic toxicity, as persistent presence in the water column leading to chronic exposures of aquatic organisms is unlikely. Therefore, this solvent is not expected to cause long-term adverse effects to aquatic organisms. It would also not be expected to have much soil leaching potential/soil mobility (Ward, D., 2011b). The SDS indicates it is not miscible with water or it is difficult to mix and it is biodegradable (N. S. Farrington and Company, 2012).

PBT Profiler estimates (US EPA, 2016b):

- Persistence: may not be persistent in water and soil and only moderately persistent in sediment
- Solubility: low but higher than hydrocarbons
- Vapor Pressure: high, is a gas at room temperature

- May have potential to leach to groundwater
- Half-life in Soil: 17 days
- Bioconcentration Factor (BCF): estimated to be 30, indicating it is not expected to bioconcentrate
- Chronic toxicity to fish possible

Scorecard Ranking (Good Guide, 2011):

- Not ranked

## 6.0: OVERALL EVALUATION

A system was developed to categorize the garment cleaning solvents and processes used in Suffolk County with a focus on increasing consumer awareness about professional garment cleaning choices. Consumer choice categories were created based on human health and environmental factors. The categories were color coded ranging from red, which represented the least preferable option, to green the most preferable option, with yellow a category between least and most preferable. The determination and factors that were used for categorizing each solvent/process is provided below.

### 6.1: Perchloroethylene

Environmental Factors: **Red**

- Detected as a contaminant in air, soil, soil vapor, groundwater, and indoor air (WHO, 2014)
- Persistent in the environment (TURI, 2012, US EPA, 2016b)
- Degradation products (e.g., TCE and vinyl chloride) are more toxic than Perc
- New generation, dry-to-dry, closed loop systems (nonvented) machines will decrease risk of environmental releases
- Common soil and groundwater contaminant in Suffolk County

Human Health Factors: **Red**

- Considered a probable human carcinogen by several agencies (US EPA, 2012a; WHO, 2014; Cal EPA, 2017)
- Concern for developmental toxicity and neurological toxicity at environmentally relevant concentrations (e.g., NYSDOH, 2010 and 2013; US EPA, 2012b)
- High exposure potential; detected in drinking water, breast milk and indoor air related to off-gassing from dry cleaned clothes (ATSDR, 2014a; NYSDOH, 2013)
- Indoor air of residences located above dry cleaners had concentrations of Perc above the US EPA RfC, the New York State Ambient Air Guideline (AAG) and the one-in-a-million risk level
- The 95$^{th}$ percentile of indoor air concentrations in New York State had concentrations above the one-in-a-million risk level. Evidence suggests that dry cleaned clothes represent a source of Perc in indoor air (ATSDR, 2014; Sherlach et al., 2011).

Data Gaps/Uncertainty: immunological effects, hematological effects, dose-response for cognitive effects

### 6.2: <u>High Flash Point Hydrocarbons</u>

Environmental Factors: **Yellow**

- High aquatic toxicity (TURI, 2012; US EPA 2016b)
- Moderately persistent in sediment (TURI, 2012)
- Biodegradable (ExxonMobil, 2015; ChevronPhillips, 2014)
- Not persistent in water (US EPA, 2016b)

Human Health Factors: **Yellow**

- Some formulations have limited evidence of cancer from animal studies (Ward, 2013, ChevronPhillips, 2014)
- Some evidence of reproductive effects (Ward, 2013)
- Skin irritant (ExxonMobil, 2015)
- Potential to contribute to ground level ozone (related to respiratory effects such as asthma) (Cal EPA, 2015)

Data Gaps/Uncertainty: Limited environmental and toxicological information on newer hydrocarbon solvents is available. Mixture of petroleum compounds which make it more difficult to make determination on toxicity and whether available studies are relevant to specific mixtures. Risk at concentrations likely to be encountered in the environment is difficult to characterize.

### 6.3: <u>Wet Cleaning</u>

Environmental Factors:

- **Green**: when wastewater is discharged to a sewer district, wastewater holding tank, or discharged in accordance with a NYSDEC SPDES permit.
- **Yellow**: when wastewater is discharged to on-site subsurface septic system without a valid NYSDEC SPDES permit, as this would represent an unpermitted industrial wastewater discharge.
  - Unpermitted discharge to an on-site sanitary system could lead to discharge of unknown constituents to groundwater
  - Potential for 1, 4 dioxane contaminant to be present in wet cleaning products that contain ethoxylated alcohols. (HERA Project, 2009)
  - Some formulations may contain ingredients that have a degree of aquatic toxicity (Adco Professional Products LLC, 2015, Kleenwite Chemical, 2015, US EPA, 1998)
  - Biodegradable (Sinsheimer, et al., 2007)

Human Health Factors: **Green**

- No health concerns expected since solvent is water
- Ingredients in detergents and spotting agents not expected to be much different than laundering products (Cal EPA, 2015)

Data Gaps/Uncertainty: Composition of wastewater, which in Suffolk County is predominantly discharged to on-site septic systems, is uncertain

**6.4: <u>Siloxane</u>**

Environmental Factors: **Yellow**

- Low persistence in water (TURI, 2012)
- Persistent in sediment and air, and moderately persistent in soil (TURI, 2012)
- Evidence of bioaccumulation (Cal EPA, 2007)
- High aquatic toxicity (TURI, 2012)

Human Health Factors: **Yellow**

- Exposure to the public living near garment cleaning establishments using $D_5$ may not pose a risk (Cal EPA, 2015)
- Canada concluded that the amount entering the environment would not constitute a danger to human health (Environment Canada and Health Canada, 2008)
- Animal carcinogen, however, relevance to humans disputed (US EPA, 2009; Cal EPA, 2007)
- Evidence of endocrine disruption and developmental toxicity (Cal EPA, 2007)
- Detected in food, human tissue and breast milk though likely due to other uses (Cal EPA, 2007)
- Cal EPA did not determine $D_5$ to be a "non-toxic" alternative to Perc (Cal EPA, 2007)

Data Gaps/Uncertainty: Potential for uterine cancer in humans is unclear. Due to other uses, the relative contribution to environmental contamination from garment cleaning compared to these other sources is unknown. Environmental data in Suffolk County are lacking, as the County does not have the analytical ability to analyze samples for Siloxane.

**6.5: <u>Liquid Carbon Dioxide</u>**

Environmental Factors: **Green**

- No releases to soil or water expected (TURI, 2012)
- Air releases possible but would not result in an overall increase in the contribution to atmospheric $CO_2$ (TURI, 2012; Cal EPA, 2015)

Human Health Factors: **Green**

- No health concerns expected

**6.6: <u>Butylal</u>**

Environmental Factors: **Green**

- Biodegradable (N.S. Farrington and Company, 2012; Ward, 2011b)
- Not persistent in water and soil (US EPA, 2016b)
- Not expected to cause aquatic toxicity (Ward, D., 2011b)

Human Health Factors: **Yellow**

- Inconclusive evidence that formaldehyde, a human carcinogen, may be present as a breakdown product (Ceballos, et al., 2015a, NTP, 2016)
- Low acute toxicity, but chronic toxicity information lacking (Ward, 2011b)

Data Gaps/Uncertainty: Inhalation exposure studies are lacking, as are studies of subchronic and chronic exposure duration. Chronic toxicity data gaps include central nervous system, reproductive and developmental effects, as well as other target organ toxicity. Environmental data in Suffolk County are lacking as the County does not have the analytical ability to analyze samples for butylal.

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# APPENDIX

## DEFINITIONS

**Persistence** is the ability of a chemical substance to remain in an environment in an unchanged form. The longer a chemical persists, the higher the potential for human or environmental exposure to it. The individual environmental media for which a chemical's persistence is usually measured or estimated are air, water, soil, and sediment.

**Bioaccumulation** is the process by which the chemical concentration in an aquatic organism achieves a level that exceeds that in the water, as a result of chemical uptake through all possible routes of exposure. Bioaccumulation includes both biomagnification and bioconcentration. In general, chemicals that have the potential to bioconcentrate also have the potential to bioaccumulate. Since a bioconcentration factor (BCF) in fish can be readily measured in the laboratory and bioaccumulation is much more complicated to determine, the BCF is frequently used to predict the importance of bioaccumulation (US EPA, 2016b).

**Bioconcentration** is the accumulation of a chemical in or on an organism when the source of chemical is solely water. Bioconcentration can also be defined as the process by which a chemical concentration in an aquatic organism exceeds that in water as a result of exposure to a waterborne chemical. Bioconcentration factor (BCF) can be expressed as the ratio of the concentration of a chemical in an organism to the concentration of the chemical in the surrounding environment. The BCF is a measure of the extent of chemical sharing between an organism and the surrounding environment.

**Biomagnification** refers to the concentration of a chemical to a level that exceeds that resulting from its diet.