Toxics Link
for a toxics-free world

CLEANING CLOTHES?

But what about environment and health!

A study on the chemical solvent PERC used in dry-cleaning

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About Toxics Link

Toxics Link emerged from a need to establish a mechanism for disseminating credible information about toxics in India, and for raising the level of the debate on these issues. The goal was to develop an information exchange and support organisation that would use research and advocacy in strengthening campaigns against toxics pollution, help push industries towards cleaner production and link groups working on toxics and waste issues.

Toxics Link has unique experience in the areas of hazardous, medical and municipal wastes, as well as in specific issues such as the international waste trade and the emerging issues of pesticides and POPs. It has implemented various best practices models based on pilot projects in some of these areas. It is responding to demands upon it to share the experiences of these projects, upscale some of them and to apply past experience to larger and more significant campaigns.

Acknowledgement

We would like to thank Mr. Ravi Agarwal, Director, Toxics Link for his continued guidance and encouragement. We would like to thank Mr. Satish Sinha, Associate Director, Toxics Link who guided us through the entire research process and helped us in shaping the study and the report.

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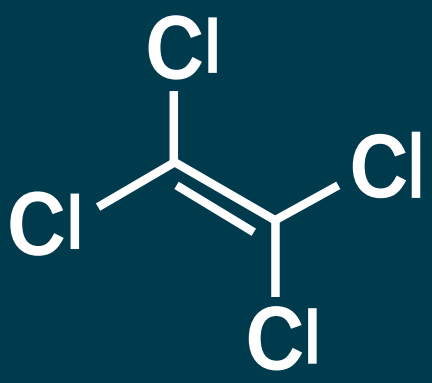
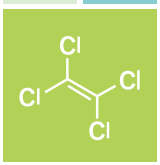


Abbreviations

ATCM	Airborne Toxic Control Measure
BLV	Biological Limit Value
EU	European Union
IARC	International Agency for Research on Cancer
OSHA	Occupational Safety and Health Administration
PERC	perchloroethylene
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
RPM	Rotations Per Minute
SPCB	State Pollution Control Board
US EPA	United States Environmental Protection Agency



Introduction

Dry-cleaning is the process of cleaning garments without water. This process typically utilizes a liquid chemical solvent to clean garments, especially those that may be too delicate for normal wet cleaning. Dry-cleaning companies use solvents to dissolve stains and remove soil or dirt while preventing fabric shrinkage and colour fading caused by wet washing. Although various chemicals are used in dry-cleaning, perchloroethylene, also known as tetrachloroethylene (or PERC), is the most favoured by dry-cleaners around the world. This solvent has many advantages for the dry-cleaning industry as it is non-flammable, can be reused, which makes it cost effective, and does not cause garments to shrink and dyes to bleed.

Despite these advantages, PERC is a problem chemical as it has been found to be toxic for both human health and the environment. In fact, several agencies such as the International Agency for Research on Cancer (IARC) have determined the high probability of PERC being a carcinogen.[1]Apart from being a health hazard, it is toxic to the environment and has been classified by the US Environmental Protection Agency (EPA) as a pollutant.[2]

Tetrachloroethylene is used mainly as a solvent for dry-cleaning and metal degreasing.

Dry-cleaning is a popular service used in most parts of India, especially urban areas. It is often used for cleaning expensive and sensitive clothing. With changing lifestyles in urban India, this service is only going to grow in the future. Though currently many solvents are being used in the dry-cleaning facilities in India, PERC is a key one. Inspite of PERC being globally considered a toxic chemical, there has been very limited research on understanding its impact on health and environment in the Indian context.

This study aims to bridge some of these gaps by understanding and documenting the current usage of PERC in the dry-cleaning industry. It also looks at issues of workers' safety and disposal practices for this chemical in the industry, as it is known to be an occupational hazard. Apart from this, the study investigates the possibility of PERC risks for consumers who use dry-cleaned clothes.

1 IARC Monographs, Volume 6, available athttps://monographs.iarc.fr/ENG/Monographs/vol106/mono106.pdf –last accessed on 22/11/2017

2 https://www.epa.gov/sites/production/files/2015-09/documents/priority-pollutant-list-epa.pdf, last accessed on 14/11/2017.

Study Framework

Objectives

The objectives of the study are:

1. To review the literature on risks associated with PERC usage in dry-cleaning facilities.
2. To understand the current usage of PERC in the dry-cleaning industry in India.
3. To document the current environment and occupational safety norms in the facilities using PERC.
4. To assess if there are any risks of PERC exposure to people through dry-cleaned clothes.
5. To assess the need for regulatory frameworks for the dry-cleaning processes using PERC in India and make recommendations.

Methodology

The study was conducted in three phases.

1. The first phase involved secondary research related to dry-cleaning and PERC.
2. The second phase involved a survey of dry cleaning facilities to understand the current practices, knowledge and safety measures.
3. The third and final phase comprised laboratory tests to assess if there were residues of PERC in dry-cleaned clothes.

Phase I

This phase involved collating information regarding the dry-cleaning process such as the chemicals used, health and environmental impacts and regulations from various sources in public domain (research papers, government websites, websites of EPA, OSHA, etc.). The following aspects are covered in the secondary research:

- Dry-cleaning process and the role of PERC
- Health and environmental risks associated with usage of PERC in the dry-cleaning process
- Regulatory frameworks globally and in India related to PERC usage in the dry-cleaning industry
- Currently available safer alternatives to PERC

Phase II

This phase was mainly used to understand if PERC was an important chemical used in the dry-cleaning industry in India and what were the practices related to it.

Commercial dry-cleaners are typically concentrated in urban centres, and hence the survey was conducted in select dry-cleaning facilities in Delhi and Kolkata. The dry-cleaning shops were selected on a random basis, but effort was made to cover different locations in these two cities.

On the basis of the secondary research, a survey questionnaire was designed to get information on the dry-cleaning process, chemicals used, health and environmental safety measures, waste discharge methods and regulations followed in dry-cleaning facilities. The actual dry-cleaning facilities could not be visited as they did not give permission for the same, and the interviews were conducted in the shops from where they received or to which they delivered clothes.

Table 1: Sample Size of Dry-Cleaners in Delhi and Kolkata

Target group	Delhi	Kolkata
Dry-cleaners	37	42
Total	79	

Phase III

This phase involved assessing if there are PERC residues in dry-cleaned clothes. This was done in two steps.

Round 1: Globally there has been only one such study on PERC residues from dry cleaned clothes and in India, this issue has not been researched so far. Hence, initially we decided to take a few representative samples to understand if there were any possibilities of such residues.

Six clothing items (comprising different materials) were collected and tested for PERC after being dry-cleaned using PERC in New Delhi. The samples included two pieces each of cotton, silk and wool. The dry-cleaned clothes were sent to an accredited lab in India. Table 2 lists each item tested for PERC in round 1.

Table 2: Clothes Given for Dry-Cleaning in Round 1

Sample no.	Items
1	Woolen Scarf
2	Woolen Sweater
3	Silk Scarf
4	Silk Blouse
5	Cotton Suit
6	Cotton Shirt

Round 2: After positive results from round 1, we increased the number of samples in the next round for a more extensive study. We decided to send the samples to two different dry-cleaning facilities using PERC, which would also give us an idea if PERC residues were similar across dry-cleaning facilities. Hence, 10 identical samples were purchased, making it a total of 20 samples. Ten samples each were sent to the two selected dry-cleaning facilities (random selection) before being sent to the lab for residue testing. One additional sample was bought and sent to the lab as a control sample—this had not been sent for dry-cleaning.

The following table lists the items sent for dry-cleaning and testing in round 2.

Table 3: Clothes Dry-Cleaned in Round 2

Sample no.	Items	Number
1	Sweater	2
2	Cardigan	2
3	Shawl	2
4	Ordinary Silk	2
5	Tussar Silk	2
6	Sofa Cover	2
7	Curtain	2
8	Jeans	2
9	Jacket	2
10	Blazer*	3

**one Blazer (control sample) not sent for dry cleaning*

Limitations of the Study

- The findings of the study are limited as the sample size is small, mainly due to resource constraints.
- Since the actual dry-cleaning plants or facilities could not be visited, the information required was sought from dry-cleaning shops. The information collected from dry-cleaning facilities regarding the process, safety measures and knowledge is also not complete as many were reluctant to share details. Workers in the dry-cleaning facilities were not very sure of the technology being used in their facilities or the disposal methods of used chemicals.
- The present study is exploratory in nature, with the objective of getting an overall view of the environmental concerns arising out of dry-cleaning solvents. This should lead to other more substantive and follow-up studies and reports.

Dry-Cleaning and PERC

Dry-cleaning as an activity came about mainly as a solution for cleaning fabrics that degrade in water and/or delicate fabrics that cannot withstand the rough and tumble of a washing machine and clothes dryer. So the use of chemicals became an alternative for cleaning such clothes. The first documented use of chemicals in textile cleaning goes back to 1690.[3] An organic solvent, the spirit of turpentine, was used to clean fat and oil stains from garments. Reports suggest that the modern history of dry-cleaning began with an accident. In the 1840s, the French textile maker Jean Baptiste Jolly's maid accidentally spilled kerosene from a lamp onto a linen tablecloth. To Jolly's surprise, the linen tablecloth became much cleaner at the spot where the kerosene was spilled. Jolly used this revelation as a basis for starting a dry-cleaning service. The first commercial dry-cleaning operation was started in Paris in the 1840s by the firm Jolly-Belin.[4]

Inventors and businesses across Europe continued to experiment with kerosene- and gasoline-based cleaning through the remainder of the nineteenth century. Henceforth, dry cleaning-operations were opened up gradually in the rest of the developed world. By late nineteenth century, turpentine spirits, camphor oil, benzene, naphtha, kerosene and white gasoline were used as dry-cleaning solvents. But soon because of incidents of fires and explosions in dry-cleaning plants, the industry across the world set out to find better alternatives. American dry-cleaner William Joseph Stoddard is credited as the first to develop a successful non-gasoline-based solvent in the 1920s called Stoddard solvent.[5] By the 1930s, cleaners started using chlorine-based solvents and found their best success with tetrachloroethylene, a compound comprising carbon and chlorine atoms. PERC became the most popular dry-cleaning solvent in the US, and the dry-cleaning industry accounted for approximately 90% of PERC consumption.[6] Subsequently, new solvents have also been introduced,but these have not found as much success or acceptance.

3 https://drycleancoalition.org/download/drycleaning-historical_developments.pdf,last accessed on 14/11/2017.
4 Ibid.
5 http://www.battistons.com/content/dry-cleaning-history,last accessed on 14/11/2017.
6 https://drycleancoalition.org/chemicals/chemicalsusedindrycleaningoperations.pdf,last accessed on 14/11/2017.

Dry-Cleaning: The Concept

Dry-cleaning means cleansing of textiles in non-aqueous solvents or without the use of water. Highly vapourizing organic solvents are commonly used as dry-cleaning fluids. Much of the dirt, soil or stain-producing substances on fabrics are organic in nature (e.g., sticky oily compounds). A common principle is used in this regard—'like dissolves like'.In wet cleaning, washing is achieved through the combined action of soap and water. Soap acts as a mediator between oil (present in dirt) and water, which are otherwise non-reacting, in other words,'unlike' in nature. In dry-cleaning, cleansing is achieved through the action of a solvent that dissolves the sticky matter due to its 'like' nature. Dry-cleaning fluids serve as a vehicle to carry away the soil.

The key steps in dry-cleaning are as mentioned below:

- Pre-treatment: The cleaner looks for stains on the clothes and treats them to make removal easier and complete.
- Dry-cleaning: The clothes are put in a machine and cleaned with a solvent.
- Post-spotting: Any lingering stains are removed.
- Finishing: This includes pressing, folding, packaging and other finishing touches.

Mechanics of Dry-Cleaning Machines

There are various models of dry-cleaning machines, but they all work on the same principle. Figure 1 describes the process flow,[7] from the time the customer takes his/her clothes for dry-cleaning till collection.

A dry-cleaning machine consists of four basic components.[8]

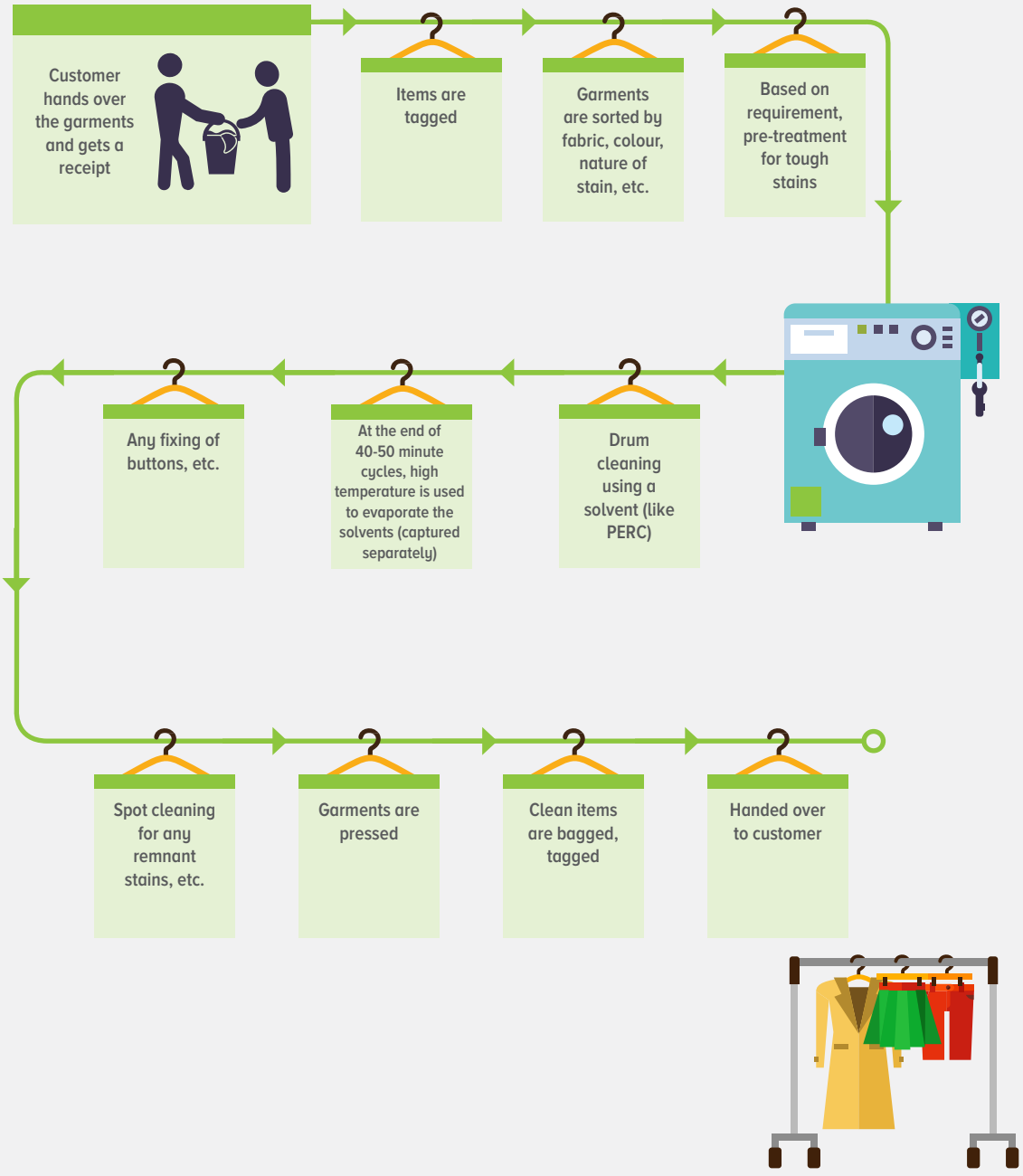
- Holding or base tank
- Pump
- Filter
- Cylinder or wheel

In a dry-cleaning machine, garments are placed in the washing or extraction chamber (also referred to as the 'basket' or 'drum'), which constitutes the core of the machine. The washing chamber contains a horizontal, perforated drum that rotates within an outer shell. The shell holds the solvent, while the rotating drum holds the garment load. During the wash cycle, the chamber is filled approximately one-third full of solvent and begins to rotate, agitating the clothing. The solvent temperature is maintained at 30° Celsius, as a higher temperature may damage it. During the wash cycle, the solvent in the chamber is passed through a filtration

7 Information compiled fromhttps://www.theguardian.com/lifeandstyle/2011/jul/29/secrets-dry-cleaning-industry,last accessed on 14/11/2017.

8 http://www.dlionline.org/What-Is-Drycleaning, last accessed on 14/11/2017.

Figure 1: Dry-Cleaning Cycle



chamber and then fed back into the chamber. This is known as the cycle and is continued for the wash duration.Filters are used to trap solid impurities.The solvent is then removed and sent to a distillation unit consisting of a boiler and condenser. The condensed solvent is fed into a separator unit where any remaining water is separated from the solvent and then fed into the 'clean solvent' tank.

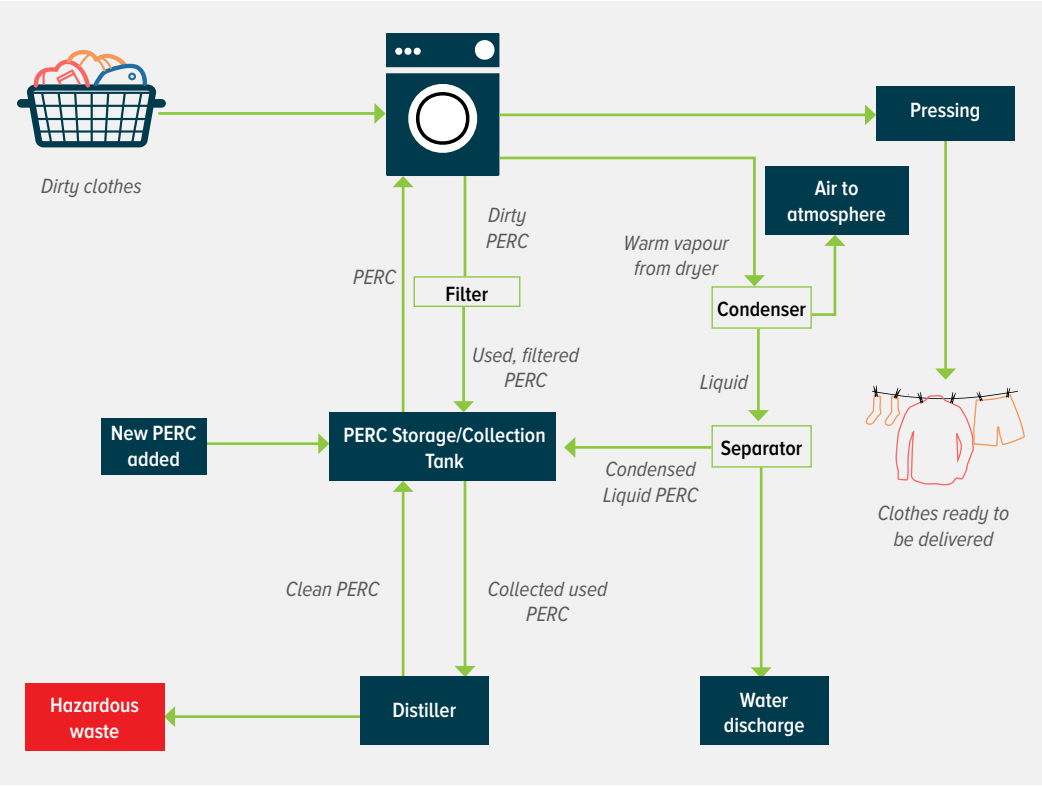
At the end of the wash cycle, the machine starts a rinse cycle where the garment load is rinsed with freshly distilled solvent dispensed from the solvent tank. This pure solvent rinse prevents discolouration caused by soil particles being absorbed back onto the garment surface from the 'dirty' working solvent.After the rinse cycle, the machine begins the extraction process, which recovers the solvent for reuse. Modern machines recover approximately 99.99% of the solvent employed. The extraction cycle begins by draining the solvent from the washing chamber and accelerating the basket to 350–450 rpm, causing much of the solvent to spin free of the fabric. Until this time, the cleaning is done in normal temperature, as the solvent is never heated in the dry-cleaning process. When no more solvent can be spun out, the machine starts the drying cycle.At this time, clothes are either transferred to a separate dryer or, on most machines, dried in the same unit, which is a closed system.

In the drying process, warm air is circulated through the cylinder to vapourize the solvent left on the clothes. The air temperature is controlled to prevent heat damage to the garments. The exhausted warm air from the machine then passes through a chiller unit where solvent vapours are condensed and returned to the distilled solvent tank. Modern dry-cleaning machines often use a closed-loop system in which the chilled air is reheated and re-circulated. The used and collected solvent is distilled for purification. Distillation separates the solvent from other waste residues such as detergents, dye, dirt and oil in order to reuse the solvent. In addition to distillation, most machines also use filters to clean the used solvent. This clean solvent is then pumped back into the holding/base tank.This results in high solvent recovery rates and reduced air pollution.[9] The filters are required to be disposed of in a hazardous waste facility.

The dry-cleaning process produces a certain amount of wastewater that generally contains very low concentrations of PERC. During the drying cycle, the temperature is raised to about 60° Celsius, which helps the chemicals evaporate faster, while still being low enough to not damage the fabric.

9 https://www.laundrybubble.com/dry-cleaning-process/, last accessed on 14/11/2017.

Figure 2: Dry-Cleaning Flow



Chemical Solvents Used for Dry-Cleaning

Petroleum-based compounds have been the most widely used solvents in dry-cleaning. At the beginning of the twentieth century, raw white gasoline was the dry-cleaning solvent of choice. Because of fires and explosions associated with the use of gasoline, it posed risks, and efforts were made to look for other solvents. Some of the commonly used solvents have been:

- **Stoddard solvent:** Stoddard solvent is a mixture of numerous hydrocarbons derived by refining crude oil. Since gasoline is highly flammable, Stoddard's solvent was developed as a less volatile alternative. From the late 1920s through the late 1950s, the Stoddard solvent was the predominant solvent in the US.[10]
- **Carbon tetrachloride:** Carbontetrachloride was the first chlorinated solvent used in dry-cleaning operations. It was commonly used in dry-cleaning by the 1930s. Because of its high toxicity and tendency to contribute to machinery corrosion, it was phased out.[11]

10 https://drycleancoalition.org/chemicals/chemicalsusedindrycleaningoperations.pdf, last accessed on 14/11/2017.
11 Ibid.

- **Perchloroethylene(PERC):** The superior cleaning ability of PERC coupled with the issue related to fire in the use of petroleum-based solvents in dry-cleaning operations resulted in the increased use of PERC.

PERC or Tetrachloroethylene

PERC is a colourless liquid, which is not flammable under normal temperature and pressure. Tetrachloroethylene was first discovered by Michael Faraday, one of the most prominent chemists in the history of science. It is also known as perchloroethylene or PERC.It is part of two classes of chemicals known as halogenated volatile organic compounds (HVOCs) and chlorinated solvents. Due to the presence of one or more chlorine atoms in their structure, chlorinated solvents are heavier than water.[12] It is a highly oxidized compound and is considered highly stable.[13] However, PERC degrades in the presence of light, heat and oxygen to form trichloroacetyl chloride and tetrachloroethylene oxide. If water is present, hydrochloric acid is generated.[14]

The advantage of PERC over water-based detergents and fabric softeners (and the reason for its popularity) is that it can remove grease-based stains and oil without shrinking or damaging clothes. It is also cheaper and can be used to clean all sorts of clothes with little supervision. But it is a synthetic and volatile organic compound, which has been found to be hazardous to humans, animals and the environment. As mentioned earlier, if PERC is spilled into the environment, then a part of it will evaporate, while the rest will infiltrate through the ground into the subsurface. It has been found to be toxic to humans at very low concentrations.[15]

PERC Concerns

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 reproduction and development. Human data on the effects of PERC exposure are mostly from occupational studies involving workers repeatedly exposed to PERC in the dry-cleaning process .In a study of breast milk in the US, tetrachloroethylene was detected in seven out of eight samples analysed.[16] Studies of PERC's effects on humans and animals have demonstrated that PERC is readily absorbed by inhalation, skin contact or ingestion. In humans, about 90% of inhaled PERC is initially retained, falling

12 https://www.environmentalpollutioncenters.org/perchloroethylene/, last accessed on 14/11/2017.
13 https://pubchem.ncbi.nlm.nih.gov/compound/tetrachloroethylene#section=Top, last accessed on 14/11/2017.
14 https://drycleancoalition.org/chemicals/chemicalsusedindrycleaningoperations.pdf, last accessed on 14/11/2017.
15 Ozonoff, David. 2013. 'Late Lessons from Early Warnings: Science, Precaution, Innovation',in Too Much to Swallow: PCE Contamination of Mains Water, pp. 76–91.Copenhagen: European Energy Agency. Available at www.eea.europa.eu/, last accessed on 22/11/2017
16 Pellizzari, E.D., T.D. Hartwell, B.S. Harris, R.D. Waddell, D.A. Whitaker and M.D. Erickson. 1982. 'Purgeable Organic Compounds in Mother's Milk,'Bulletin of Environmental Contamination and Toxicology, 28: 322–328. last accessed on 22/11/2017

to about 50% after an eight-hour exposure.[17] Uptake of PERC is increased by exercise. Uptake through the skin is usually much less than through the respiratory tract.[18]

Health Effects on Workers: Employees working in dry-cleaning operations may be exposed to PERC while performing both routine tasks and machine maintenance. Activities that result in elevated exposure include:[19]

- Loading dirty clothes into the machine (when PERC-contaminated air is displaced and forced out of the machine);
- Removing clothes, especially thick items, before the drying cycle is finished;
- transferring solvent-laden clothes into the dryer;
- cleaning lint and button traps;
- raking out the still (distillation unit residue);
- changing the solvent filter;
- maintenance of water separator; and
- handling and storage of hazardous waste.

Tetrachloroethylene or PERC is a PROBABLE CARCINOGEN in humans.There may be no safe level of exposure to a carcinogen, so all contact should be reduced to the lowest possible level.

Apart from these, uncontrolled emissions or so-called fugitive emissions from dry-cleaning machines can also expose workers to high levels of PERC. Other possible sources of PERC exposure not directly associated with the dry-cleaning equipment include pressing freshly dry-cleaned clothes or using a PERC-based spotting agent.[20]

Long-term exposure to PERC can result in neurological effects, such as dizziness and diminished cognitive ability, as well as damage to the liver and kidneys.[21] High levels of exposure in enclosed spaces, even for short periods of time, can cause respiratory failure and even death. Since workers in dry-cleaning facilities are exposed to PERC five to six days a week and that too for eight hours or more, they have an exceptionally high risk of suffering from some of effects. Short-term inhalation of tetrachloroethylene at very high level scan 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. Exposure to very high levels of PERC has resulted in death.[22]

Tetrachloroethylene crosses the placenta and can be found in breast milk; therefore, the fetus and nursing newborn may be at increased risk.

17 Recommendation of the Scientific Committee on Occupational Exposure Limits for Tetrachloroethylene (Perchloroethylene). Available atec.europa.eu/social/BlobServlet?docId=6409&langId=en, last accessed on 22/11/2017
18 Ibid
19 https://www.osha.gov/dsg/guidance/perc.html, last accessed on 14/11/2017.
20 Ibid.
21 McKeown, David. 2007.Reducing Health Impacts of Perchloroethylene from Dry Cleaning in Toronto, Technical Report. Toronto, Ontario:Toronto Public Health.
22 Ibid

Occupational exposure to PERC is associated with adverse reproductive effects such as menstrual disorders, miscarriages and reduced fertility.[23] In a retrospective study of women who worked in dry-cleaning and laundry facilities, high levels of PERC were found to increase the risk of spontaneous abortions. PERC in the maternal bloodstream crosses the placental barrier to reach the fetal bloodstream. PERC concentrates in breast milk since it is highly fat-soluble and is long-lived in the human body. Breastfeeding infants therefore may be exposed to PERC though their mother's milk.[24]

In addition, if the dry-cleaning machine using PERC is not properly insulated, it can seep through walls and expose residents and businesses adjacent to the cleaner. Such exposure can have long-term health effects on residents, similar to those found among workers.[25]

Impact on Consumers: Most of us give some clothes, especially woolens and silk clothing, for dry-cleaning. PERC off-gases from clothes dry-cleaned using this chemical. Short-term exposure to PERC can cause dizziness, rapid heartbeat, fatigue, headaches, confusion, nausea, and skin, eye and respiratory tract irritation.[26]

A team of researchers in Georgetown University, Washington DC, USA published a study in 2011 on PERC remnants in dry-cleaned clothes made of different fabrics.[27] They used gas chromatography/mass spectrometry (GC/MS) to examine the quantity of PERC in different types of fabric, namely, wool, polyester, cotton and silk. Dry-cleaning was carried out in seven facilities out of which two units claimed to be green. They found that polyester, cotton and wool dry-cleaned in five out of the seven units retained considerable amount of PERC, whereas silk samples from none of the units retained a detectable concentration of the same. The two green dry-cleaners did not show any detectable concentration of PERC in any of the fabrics.

The team also sent the fabrics for multiple cycles of dry-cleaning to see if PERC accumulated successively and to what extent. After a single cycle, retention of PERC on polyester was found to be the highest, followed by wool and cotton. After one cycle, polyester retained between 28.03 and 56.76 nmol of PERC per cm^2 of fabric, whereas cotton retained between 10.70 and 24.66 nmol of PERC per cm^2. Wool retained between 16.43 and 47.58 nmol of the same per cm^2 of the fabric tested. The study also found that the PERC concentration increases with the number of dry-cleaning cycles. The concentration in polyester did not show an increase after three dry-cleaning cycles, whereas in the case of cotton, the concentration ceased to increase after two cycles. Wool, on the other hand, continued to show an increase in the concentration of

23 Ibid
24 Ibid
25 https://sfenvironment.org/article/perchloroethylene-perc-cleaning, last accessed on 14/11/2017.
26 https://www.atsdr.cdc.gov/phs/phs.asp?id=263&tid=48, last accessed on 14/11/2017.
27 Sherlach, K.S.,A.P. Gorka,A. Dantzler and P.D. Roepe. 2011. 'Quantification of Perchloroethylene Residues in Dry-Cleaned Fabrics',Environmental Toxicology and Chemistry, 30: 2481–2487.

PERC after every cycle. The team also found that PERC could vapourize from the fabric under ambient room air conditions.[28]

Environmental Effects: PERC has been shown to contaminate soil, water and air. It is quite volatile and so pollutes indoor and outdoor air.[29] PERC may escape into the outdoor air through windows, doors, ventilators and air-conditioning systems in dry-cleaning units during cleaning, purification and waste disposal phases. It can remain in air for several weeks, and after a few days, it breaks down into chemicals that may be toxic.

PERC may penetrate into the ground in liquid form through spills, leaky pipes and tanks, machine leaks and from improperly handled waste. It may also enter water bodies in the same way.

PERC spills are considered to be severe environmental accidents as PERC can seep into the soil and reach drinking water aquifers. Studies indicate that high levels of PERC were detected in the groundwater samples from some parts of California's municipal wells around 1989. This discovery led to extensive investigations that identified over 50 potential contaminant sources, including a number of dry-cleaning facilities.[30] In 1990, the EPA proposed national emission standards to limit PERC emissions from dry-cleaning plants, which became part of the Clean Air Act amendments. Thus, began the numerous legislations and decisions to phase out PERC from the dry-cleaning industry.

Tetrachloroethylene slowly decomposes in water to form acids such as hydrogen chloride. It also decomposes slowly with heating, and with exposure to ultraviolet light or on contact with hot surfaces, itformsthe toxic hydrogen chlorideand phosgene gases.

During the dry-cleaning process, discharges of the solvents (including PERC) to the environment (including fugitive emissions) can happen under several circumstances, such as:

- 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; and
- pressing freshly dry-cleaned clothes.

Alternatives to PERC

- **Brominated solvents/n-propyl bromide(nPB):** Many users in various fields such as aerospace, electronics and other applications where precision cleaning is required have

28 Ibid
29 https://www.health.ny.gov/environmental/chemicals/tetrachloroethene/, last accessed on 14/11/2017.
30 https://drycleancoalition.org/chemicals/chemicalsusedindrycleaningoperations.pdf, last accessed on 14/11/2017.

used stabilized nPB safely. It was applied to dry-cleaning in 2005.[31] Health concerns and increased regulation of PERC (for garment cleaning) have resulted in increasing use of nPB as a relatively inexpensive and unregulated drop-in substitute. However, scientific evidence indicates that nPB is not a safer substitute. A recent study reveals that long-term exposure to nPB leads to neurotoxicity in humans and animals.[32] According to the EPA, nPB has a low tendency to concentrate in living organisms, is moderately mobile in soil, and tends to volatilize and break down easily in water.

- **Liquidsilicone (decamethylcyclopentasiloxane or D5):** This dry-cleaning and industrial solvent uses a silicone-based solvent called siloxane. Though considered friendlier to the environment, it is more expensive. It degrades within days in the environment to silicon dioxide and trace amounts of water and carbon dioxide and produces non-toxic, non-hazardous waste. Toxicity tests show that exposure to the solvent increases the incidence of tumors in female rats (no effects were seen in male rats).This led the EPA to suspect that it may be a carcinogen. However, further research has concluded that the effects observed in rats are not relevant to humans because the biological pathway that results in tumor formation is unique to rats.
- **Glycol ethers:** These chemical solvents are reported to be more environmentally friendly than PERC and also may be more effective in certain cases. Dipropylene glycol tertiary butyl ether (DPTB), one of the chemicals in this category, may end up becoming a future substitute or replacement for PERC. It has a much higher flashpoint and a level of solvency that is equal to or greater than PERC and other glycol solvents that are presently being used in dry-cleaning.
- **Liquid carbon dioxide:** Use of this chemical has actually been rated by some as better than conventional methods (i.e., PERC). However, the dry-cleaning and laundry industry does not agree and has described it as having a low cleaning ability. At the same time, use of this chemical cleaning process requires some expensive machinery, making this a non-viable option for smaller and medium sized dry-cleaners.

Although the process of dry-cleaning fabric can vary, all dry-cleaning operations generally follow a method. After the purification process, filters containing the solvent in low concentrations and certain solvent residues such as PERC are required to be managed and disposed of as hazardous waste. Dry-cleaners can send them to special facilities for recycling or incineration. Proper disposal of PERC and other cleaning solvents is a priority in order to prevent it from seeping into the environment.

31 Dingess, John, Richard Morford and Ronald L. Shubkin. 2011. 'n-propyl Bromide', in Barbara Kanegsberg and Edward Kanegsberg (eds), Handbook for Critical Cleaning, Second Edition, pp. 149–168.Boca Raton, FL: Taylor and Francis.

32 Ichihara, Gaku. 2012. 'Neurotoxicity of 1-bromopropane: Evidence from Animal Experiments and Human Studies',Journal of Advanced Research, 3(2): 91–98. Last accessed on 22/11/2017

Study Findings

This section has two parts. The first part documents the results from a survey conducted in Delhi and Kolkata to understand the use of PERC technology in dry-cleaning facilities and also the disposal mechanism of spent PERC. Moreover, the survey assessed the knowledge levels of workers regarding PERC exposure and harmful health impacts. The second part analyses the results from the laboratory testing of dry-cleaned garments for PERC remnants, as this could be a potential risk to consumers.

Section 1: Use of PERC in Dry-Cleaning Facilities

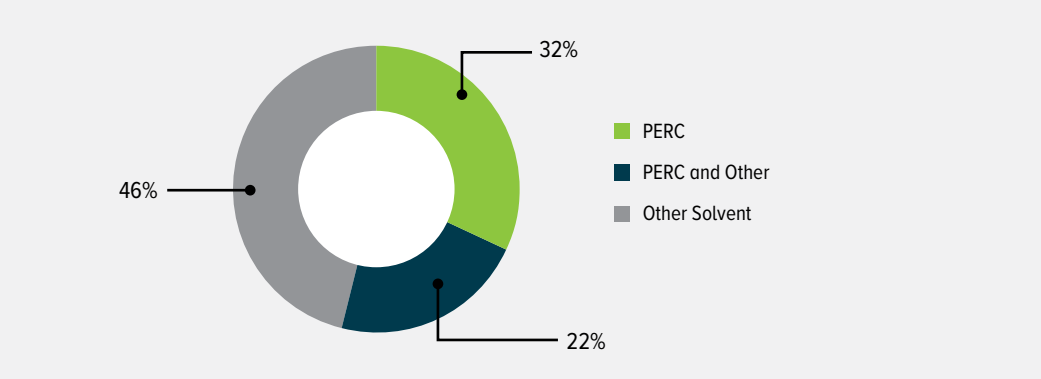
The survey conducted in a total of 79 dry-cleaning facilities, 37 in Delhi and 42 in Kolkata, revealed that PERC was being used in many facilities. Other solvents, especially Stoddard solvent, were also popular. Some facilities were found to be using two technologies for dry-cleaning.

Table 4: Dry-Cleaning Facilities

City	Total units surveyed	PERC	PERC plus other	Other solvent	Not disclosed
Delhi	37	12	8	17	-
Kolkata	42	1	2	20	19
Total	79	13	10	37	19

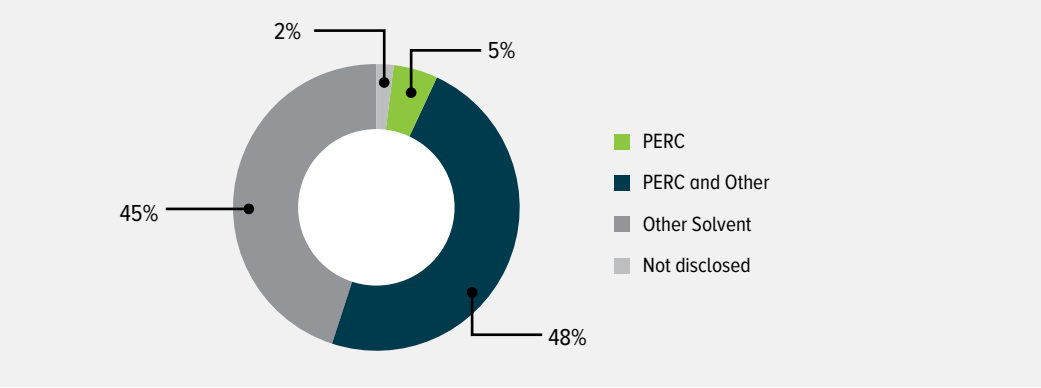
Overall around 29% of the surveyed units were using PERC, with 57% of these using only PERC as a solvent, whereas the remaining 43% were using more than one solvent and PERC was one of the solvents being used. In Delhi, the use of PERC technology was comparatively much higher—20 facilities, out of 37, were using PERC, with 8 using both PERC and another solvent. Alternative chemicals being used in dry-cleaning in Delhi are mainly mineral turpentine oil (MTO), popularly known as white spirit or the Stoddard's solvent.

Figure 3: Chemicals Used in Dry-Cleaning Facilities in Delhi



In Kolkata, the scenario was quite different as workers in most units refused to share or did not know the chemicals that were used in their facilities. Only three of the surveyed units admitted to using PERC as the solvent in their facilities. It was not clear as to why the usage was so different in two different metro cities in the country.

Figure 4: Chemicals Used in Dry-Cleaning Facilities in Kolkata



In Kolkata, benzene, ethylene, caustic soda and ethanol are most commonly used by dry-cleaners along with certain branded stain removers available in the market, like Rit and Ala.

The main reasons for using PERC, according to the units surveyed, are as follows:

- Latest technology
- Better cleaning ability in comparison to other solvents
- Fabric friendly—does not shrink clothes or spoil their texture
- Shine

- Eco-friendly
- No smell
- Gentle on skin
- Better finishing in comparison to other solvents

Most of the units were unable to specify the amount of PERC used monthly in their facilities. The PERC usage in the facilities varied quite a bit, primarily depending on the size of the operation. In Delhi, the average consumption of the chemical is between 20 liters and 40 liters monthly, whereas in Kolkata, the amount ranged between 6 liters and 18.5 liters per month.

Process

Dry cleaners in both the cities follow the same dry-cleaning process as depicted in Figure 5.

Figure 5: Process

Most PERC dry-cleaners reported that the chemical was used multiple times.

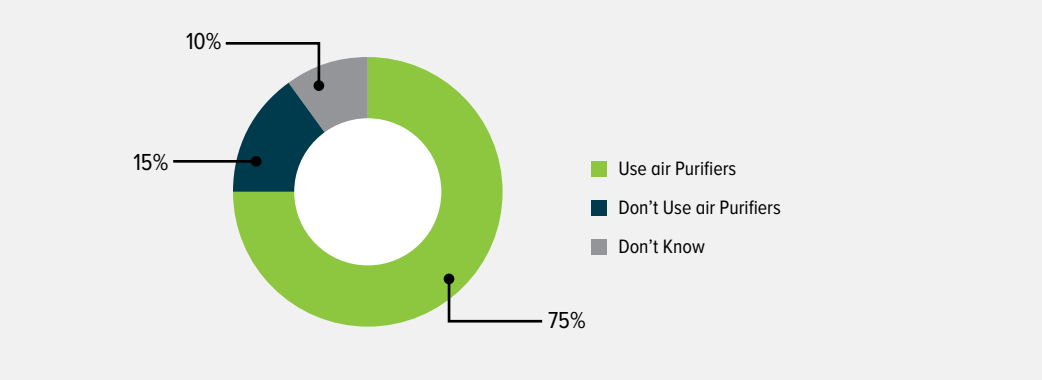
Awareness amongst Workers

The survey among the workers in the dry-cleaning units indicated that most of them lacked awareness about the importance of safely handling PERC and its detrimental impact on human health, water, air and vegetation.

As a result, fugitive emissions from machinery are sometimes not taken care of. Some steps involve manual work and the workers in many dry-cleaning facilities lack even basic safety gear like gloves. Nor do they know about the ill effects (such as nausea, dizziness and respiratory issues) of handling PERC in this way.

In Delhi, 75% of the units dependent on PERC reported that they have air filters or purifiers in their facilities and 60% have safety guidelines for chemical usage. In Kolkata, none of the units using PERC reported having air purifiers or safety guidelines.

Figure 6: Use of Air Purifiers in PERC-Dependent Dry-Cleaning Units in Delhi



Few of the dry-cleaning units using PERC in Delhi provide their workers with personal protective equipment (PPE), mainly limited to masks (75%) and gloves (75%). While 20% of the PERC-using units provide their workers with aprons, none of the units provide other essential safety equipment like shoes or other tools. In Kolkata, the workers in the PERC-dependent units do not use any PPE or tools.

Awareness on Disposal Rules

According to the Hazardous Waste Management Rules 2016, if the concentration of waste is equal to or more than the permissible limit, it should be considered toxic and must be disposed of as per the disposal procedure prescribed in the rules. Permissible concentration limit of PERC in wastewater is 0.7 mg/l.

The dry-cleaners in both the cities appeared to be unaware of this rule, and therefore, no standard guidelines or procedures are being followed for the disposal of PERC.

Some of the other key findings of the survey are as follows:

- In Delhi, 14 out of the 20 PERC units, i.e., 70% of the PERC facilities reuse PERC before disposing it; the rest did not know or share any information.
- All the facilities dispose of the PERC waste in dustbins or drains, or bury it underground.
- None of the PERC facilities were aware if the wastewater was being treated before being disposed of.

Section 2: PERC in Dry-Cleaned Clothes

Perchloroethylene has long been recognized as an effective dry-cleaning solvent, and today it is one of the most commonly used solvents in dry-cleaning shops. However, as a volatile organic solvent, PERC may pose serious health hazards if exposure is not properly controlled. Though there have been various studies to assess the risk to dry-cleaning workers, there has been little research on understanding the risk PERC poses to consumers of dry-cleaned clothes. This section documents the findings from the laboratory test conducted to assess if there are PERC remnants in dry-cleaned clothes that could pose a risk to consumers or the general public from using dry-cleaning facilities.

As mentioned earlier (see 'Study Framework'), the testing of dry-cleaned clothes was carried out in two rounds. In the first round, a small sample size was taken to assess if there are any possibilities of remnants. In the second round, the sample size was increased.

Round 1: Six samples were tested in this round. Different fabrics were included in this round—two woolen, two silk and two cotton. This was primarily done to understand if any particular material was more prone to retaining the chemical. The samples were sourced in-house and were used pieces of garments. The samples were sent to a dry-cleaning facility in Delhi (Dry-Cleaner A). The dry-cleaned samples were sent to an accredited lab for testing. PERC was detected in three out of six garments. Both the silk samples were detected with PERC. The concentration level in the silk blouse was found to be the highest among all the sampled items. It was undetected in the cotton garments. Though the sample size was small, it indicated that cotton garments did not retain any traces of PERC after dry-cleaning.

The fact that 50% of samples were detected with PERC concentration was an indication that dry-cleaned clothes do retain some PERC and this might be a cause of concern. Based on these results, we decided to expand the study and do another round of testing, with an increased number of samples.

The following table has listed the concentration of PERC in different dry-cleaned garments that were tested for PERC in round 1:

Table 5: PERC Concentration in Clothes (Round 1)

No.	Item	PERC concentration (mg/kg)
1	Woolen Scarf	15.5
2	Woolen Sweater	Not detected
3	Silk Scarf	4.1

No.	Item	PERC concentration (mg/kg)
4	Silk Blouse	61.4
5	Cotton Suit	Not detected
6	Cotton Shirt	Not detected

Round 2: For this round of testing, 21 garment pieces were purchased from the market. The samples were randomly selected, but an effort was made to include different kinds of fabric, for example, silk, woolen and nylon. As the first round of the study found no traces in cotton garments, in this round, we excluded cotton garments, except jeans,selected because of its thick texture. We also mainly picked up garments that are commonly sent for dry-cleaning in most Indian households, like sweaters, silk and jackets.

As mentioned in the 'Study Framework', the samples were bought in duplicate (except the blazer—bought in triplicate). In Delhi, 10 samples were sent to each of the two dry-cleaning facilities chosen randomly. Both these facilities are using PERC and had been approached for the initial survey of dry-cleaning facilities. Though one of them had responded to our survey and shared detailed information regarding workers' awareness and disposal, the other had refused to share details.

The dry-cleaned clothes were then sent to an accredited laboratory for testing of PERC residues (Test method: GTP_Chem_CPS_2517IB.2016, Place 1g±0.1g uncut sample (single piece) into a headspace vial and seal it. Incubate the sample @90°C±2°C – VOCs C. Proceed for HS-GC-MS analysis. Calculate the value against standard*)

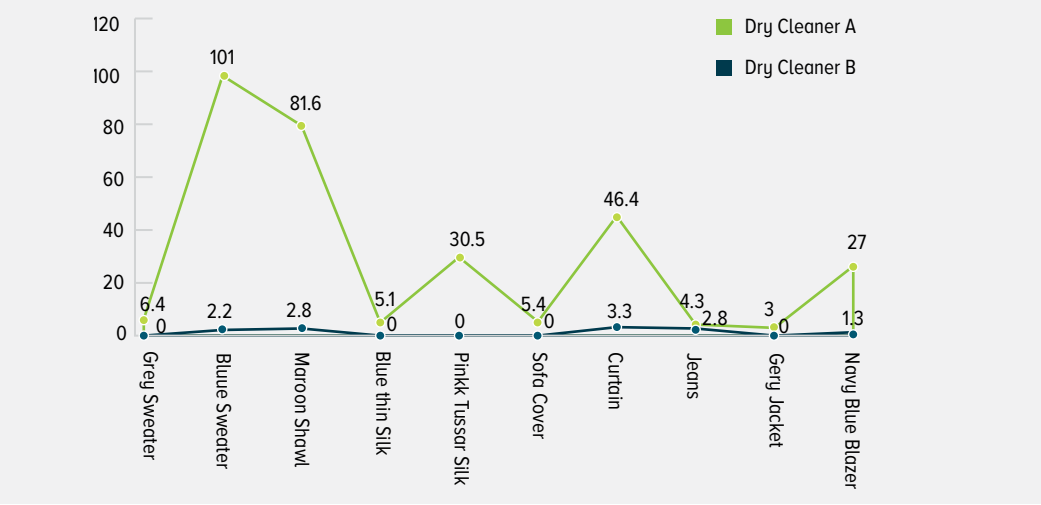
Reproduced from the test report from the laboratory.

The results were very interesting as there was a lot of variation in terms of PERC residue in different garments. Out of the 20 dry-cleaned garment samples, 15 samples were detected with PERC concentrations. PERC residue ranged from 1.3 mg/kg to 101 mg/kg. The control sample was not detected with any PERC concentration, thereby indicating that the PERC residue was coming from the dry-cleaning process. The usual practice of putting dry-cleaned clothes in plastic covers to avoid dust accumulation might also be contributing to PERC residues being retained in the garments.

Table 6: PERC Concentration in Clothes (Round 2)

Sample no.	Sample description	PERC concentration (mg/kg)	
		Dry Cleaner A	Dry Cleaner B
1	Grey Sweater	6.4	0
2	Blue Sweater	101	2.2
3	Maroon Shawl	81.6	2.8
4	Blue Thin Silk	5.1	0
5	Pink Tussar Silk	30.5	0
6	Sofa Cover	5.4	0
7	Curtain	46.4	3.3
8	Jeans	4.3	2.8
9	Grey Jacket	3	0
10	Navy Blue Blazer	27	1.3
Control Sample: Navy Blue Blazer		0	0

Figure 7: PERC Residue from Different Dry-Cleaners



It was interesting to note that the two dry-cleaning facilities gave very different results. All the dry-cleaned clothes from Dry-Cleaner A showed traces of PERC, ranging from 3 mg/kg to 101 mg/kg. The highest concentration was detected in a sweater (101 mg/kg). In contrast, only five garments from Dry-Cleaner B were detected with PERC residue, ranging from 1.3 mg/kg to 3.3 mg/kg, making the concentrations much lower than the other facility. Though it is difficult to draw conclusions, it is likely that the different concentrations detected in the two dry-cleaning facilities may be the result of different processes followed in the two units.

Though the study did not scientifically look at this particular aspect, an interesting observation can be made from the results. It appeared that the residue concentration was found to be more in clothes made of thicker or denser material. The blue sweater (sample no. 2) that was detected with the highest concentration was much thicker than most other garments sent for testing in round 2. Sample no. 5, Tussarsilk, was also detected with a higher level of PERC compared to the other silk sample (sample no. 4), which was a thin variety of silk. In round 1 also, the silk blouse (sample no. 4) was made of a few layers of cloth and hence was fairly thick, which probably led to more retention of PERC. Though it is difficult to make a direct correlation, thickness may be a factor.

Results indicate that more testing for PERC levels in other fabric types and in other dry-cleaning facilities is clearly warranted. However, a key question arises from this initial data: Do the measured PERC residues found in these fabric samples constitute a risk to human health? In this regard, it is important to note that PERC exposure has been linked to a number of health problems, including kidney and liver dysfunction, neurological disorders, including loss of motor function and visual ability, and several forms of cancer.Though not many studies have been carried out on the issue, inhalation of PERC vapours has been recognized as one route of exposure.

Lack of past studies also makes it difficult to understand what concentration of PERC residue would pose a risk to human health. But it must be pointed out that the some of the concentrations found in our study were much higher than the earlier study on dry-cleaned garments.

Legal Framework around PERC

Existing PERC Legislations around the World

Europe: PERC has been identified as a problem chemical in Europe and though no European Union (EU) country has banned PERC for use in dry-cleaning, a majority of EU member states have implemented stringent requirements for the use of PERC in dry-cleaning. Proper enforcement of existing regulations has been seen as sufficient to ensure safe handling and protection of workers and the general public around dry-cleaning shops.[33]

PERC use in dry-cleaning is covered by the European Solvents Emission Directive and by the EU Regulation on Registration, Evaluation and Authorization of Chemicals (REACH). Risk assessment under REACH showed that PERC could be used safely for dry-cleaning with the help of modern closed equipment. This helps in meeting emission norms of the EU Solvents Emission Directive.

The reasons for which PERC has not been banned are as follows:

- The use of PERC in dry-cleaning has been registered under REACH in 2010. The risk assessment for the use of PERC in dry-cleaning under REACH could demonstrate safe use in this application with modern closed equipment.
- The use of PERC in modern closed dry-cleaning equipment fulfills the emission requirements of the EU Solvents Emission Directive.

However, it strongly recommends the use of modern closed equipment of the best available technology.

Within Europe there are variations in regulations on the use of PERC. Denmark prohibits the use of PERC in new facilities after 2020. The French ministries of Ecology and Labour have announced a ban/restriction on the use of PERC in dry-cleaning facilities.The use of the

33 http://www.chlorinated-solvents.eu/index.php/regulatory-compliance/per-in-dry-cleaning, last accessed on 14/11/2017

substance is not permitted in new facilities located adjacent to residential properties. The ban will be implemented in stages for different facilities, with a total ban effective from 1 January 2022.

The EU recommendation for an occupational exposure limit (OEL) by the Scientific Committee on Occupational Exposure Limits (SCOEL) is 20 ppm (human repeated dose toxicity via inhalation as an eight hours time weighted Average value) for workers and is supported by European Chlorinated Solvents Association (ECSA). The recommendation for short-term (15 minutes) exposure limit is 40 ppm.[34]

SCOEL recommends biological monitoring of a BLV of 0.4 mg tetrachloroethylene per litre whole blood, at a sampling time prior to the last shift of a workweek (16hours after the last preceding shift). As a non-invasive alternative, a BLV of 3 ppm tetrachloroethylene in end-exhaled air is recommended (sampling time: prior to the last shift of a workweek, i.e., 16 hours after the last preceding shift).

Table 7: PERC Limits

Occupational exposure limits	8-hour TWA* (mg/m^3)	8-hour TWA (ppm)	15-min STEL# (mg/m^3)	15-min STEL (ppm)
SCOEL	138	20	275	40

**time-weighted average (TWA)*
#short-term exposure limit (STEL)

The eight-hour TWA is set at much lower levels in some of the Nordic countries, the lowest around 6ppm in Norway and 10 ppm in France.[35]

USA: In the US, on 9 December 1990, Clean Air Act amendments were made where EPA proposed national emission standards to limit PERC emissions from dry-cleaning plants. Then in 1994, EPA promulgated technology-based emission standards to control emissions from dry-cleaning facilities. In September 1996, the National Emission Standard Hazardous Air Pollutants (NESHAP) was issued. Requirements included dry-cleaning machinery maintenance, recordkeeping and monitoring. Finally, in 2006, the final rule for National Perchloroethylene Air Emissions Standards for Dry Cleaning Facilities (40 CFR Part 63) was issued. This was a revision of standards promulgated on 22 September 1993. New dry-cleaning machines installed in residential buildings are now not allowed to use PERC.[36] The limit set by USEPA for PERC

34 https://echa.europa.eu/documents/10162/08ebe33b-736e-49b2-9537-f425b05c2a82 (p. 48), last accessed on 14/11/2017
35 https://academic.oup.com/annweh/article/55/4/387/234936/Exposure-to-Tetrachloroethylene-in-Dry-Cleaning, last accessed on 22/11/2017
36 http://www.chlorinated-solvents.eu/index.php/regulatory-compliance/per-in-dry-cleaning, last accessed on 22/11/2017

concentration in the air is 30 microgram per m^3 and the limit set for its concentration in drinking water is 0.005 mg/l(or ppb). OSHA has established 100 ppm as the PERC exposure limit in the workplace for an average of 8 working hours. The American Conference of Governmental Industrial Hygienists, on the other hand, has set 25 ppm as the limit in the workplace. No standards have been prescribed for concentration of PERC in the air.[37]

In 2007, the California Air Resources Board adopted the Airborne Toxic Control Measure (ATCM) to phase out dry-cleaners' use of PERC by 2023.On 27 December 2007, the approved dry-cleaning ATCM and the requirements for PERC manufacturers and distributors became state law.

The EPA had issued revised NESHAP standards that affect New York State dry-cleaning facilities that use PERC. Dry-cleaning machines making use of PERC were not to be installed after 13 July 2006, and those that were installed between 2005 and 2006 were supposed to eliminate PERC use by 2009. Also, these were not allowed to operate from residential buildings. They would either have to move to a non-residential building or switch to an alternative solvent. The units that were installed in residential buildings before December 2005 are supposed to eliminate PERC use by 2020.

Canada: Canada also recognized the ill effects of PERC early on, around the early 1990s. PERC was added to the list of toxic substances in Schedule 1 of the Canadian Environmental Protection Act, 1999 on 29 March 2000. The Tetrachloroethylene (Use in Dry Cleaning and Reporting Requirements) Regulations became law on 27 February 2003 and were published in the Canada Gazette, Part II on 12 March 2003. The purpose of the regulations is to reduce PERC releases to the environment from dry-cleaning facilities.

The Canada Labour Court has prescribed the occupational limit of PERC to be 25 ppm and the short-term exposure limit (15 minutes)to be 100 ppm. These reductions are met by requiring more efficient dry-cleaning machines, by minimizing spills of PERC, and by managing the collection and disposal of residue and wastewater that contain PERC.

Regulations on PERC in India

According to the available information, the dry-cleaning industry in India does not have any specific regulatory framework to govern its functions. But the chemicals used in the process, depending upon their toxicity, are regulated. PERC or tetrachloroethylene is listed as a hazardous chemical under the Manufacture, Storage and Import of Hazardous Chemical (Amendment) Rules, 2000.

37 https://www.atsdr.cdc.gov/csem/csem.asp?csem=15&po=8, last accessed on 22/11/2017

Dry-cleaning waste, that is, spent solvents or the residue/muck generated from recovery of spent solvents from dry-cleaning operations, may be classified as hazardous waste as per Class A37 of Schedule-II of Hazardous Wastes Management Rules, 2016, which may require authorization from concerned State Pollution Control Boards (SPCBs). According to the rules, the permissible concentration limit for 'tetrachloroethylene' should not exceed 0.7 mg/l in any waste.

During our extensive research, we did not come across any standards related to PERC besides this. No occupational exposure limits for PERC in India were found. The information above is believed to be accurate and represents the best information currently available to us.

Conclusion and Recommendations

Tetrachloroethylene or PERC is the dominant solvent used in dry-cleaning worldwide. Its usage in the dry-cleaning industry has been under a scanner for long and has resulted in many studies to look at the effects of exposure, mainly to workers. PERC has been recognized globally as a chemical with health and environmental impacts. It has been recognized as a possible carcinogen and though its usage has not been banned, there have been restrictions on it in many countries.

Research in many countries has shown presence of PERC in indoor air in dry-cleaning facilities and in nearby areas. It has been clear that dry-cleaning workers who routinely breathe excessive amounts of the solvent vapour or spill PERC on their skin are at risk of developing health problems. But there has been very limited work on PERC residues in dry-cleaned clothes. During our research, we came across only one study that looked into this aspect.

In India, where the dry-cleaning industry is on a growth path, there has been no work on this issue, whether it is in terms of PERC exposure of workers or PERC residues in dry-cleaned clothes. The purpose of this study was to understand PERC usage and practices in the Indian dry-cleaning industry and to assess if there were PERC residues in garments that were subjected to the dry-cleaning process. The objective was met through a survey of dry-cleaning units in two cities, namely, Delhi and Kolkata, and the testing of dry-cleaned clothes for PERC.

The results indicate that though all facilities are not using PERC as a primary solvent, a large number of them are. And the key concern from the workplace perspective was the little understanding or awareness regarding the hazards of using PERC among the workers or unit owners. Limited use of PPE in the facilities also indicates their level of understanding and knowledge on the exposure risks. Though under the study, there was no provision to evaluate the PERC exposure levels of workers, this is essential for promoting safer use of the chemical in workplaces. The workplace study becomes critical as this industry consists of many small and scattered workplaces.

The key part of the study was testing of dry-cleaned clothes for PERC residue and the results are startling and raise concerns. Out of the 20 garments sent for dry-cleaning and then testing, 15 were detected with PERC. The varying concentration found might be due to various factors such as material and thickness. But what needs to be underlined is that PERC is retained in dry-cleaned clothes and there is a real possibility of exposure to customers, which could include children and the elderly. The fact that there is hardly any framework to regulate this, except in relation to waste discharge, raises a concern.

The study did not reveal conclusively if PERC usage is on an increase, but if we go by the global trend, PERC might become a more commonly used solvent in India in future. Hence, there is a need to improve its handling and management. Awareness needs to be spread among dry-cleaners and consumers about the range of detrimental effects it has on human health and the environment. Further studies will be required to assess the quantum of risk and evolve best practices and effective alternatives. This will eventually pave a path for regulations to standardize its use in India and have norms for residues and occupational exposures. Studies in Nordic countries illustrate that it is possible over time to control chemical exposures with better practices. Though the study has not explored this, dry-cleaning in institutions like hospitals and hotels might be also using large quantities of PERC and may be exposure points.

Preventive Measures

Avoid skin contact with tetrachloroethylene.

Machine Design and Maintenance

Dry-cleaning machines, especially the ones with transfer mechanism, can expose workers to high amounts of PERC, particularly during transfer of solvent-laden clothing from washer to dryer. This technology has evolved over the decades and the newer machine designs (closed looped) substantially reduce the amount of PERC vapours released into the air, inside the unit as well as outdoors. This not only results in cost saving as more PERC is recovered for reuse but also leads to safer working conditions and a cleaner environment. Retrofitting the dry-cleaning machinery with emission control mechanisms to reduce fugitive emissions is also a tried and tested way of reducing exposure to PERC.

OSHA also suggests that routine machine maintenance combined with detection and timely repair of identified leaks can be extremely effective in controlling the release of PERC vapours. Appropriate PPE needs to be worn during maintenance activities to ensure protection from hazards.

Adherence to proper methods may also ensure minimal residue of the chemical in the dry-cleaned clothes.

Ventilation

Adequate ventilation is a must in dry-cleaning units. General ventilation through overhead fans and local exhaust ventilation can help reduce PERC levels within the units. This is especially required around the machine door to control vapours when the door is open.

Proper ventilation of the clothes before being handed over to consumers might be a step required to reduce the PERC residue in the clothes. Consumer may also air it before use.

PPE

Personal protective equipment (PPE) like aprons, gloves, goggles and respirators can be of help to workers and can reduce the risk of PERC exposure.

Training

Workers engaged in dry-cleaning operations must go through training on PERC risks and measures to protect themselves from the hazards of PERC. Training should also be provided to ensure proper usage of PPEs. Worker training should also include measures to reduce environmental risks due to PERC usage.

Accident Reporting

Dry-cleaning facilities should have a proper accident reporting system to ensure any leakage or exposure is documented and steps are taken to mitigate them.

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