SUBSPORT Specific Substances Alternatives Assessment – Perchloroethylene

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Table of content

1. Perchloroethylene hazards profile

Characterising perchloroethylene based on its inherent hazards is an essential component of conducting an alternatives assessment. This approach allows the reviewer to assess whether or not an alternative is indeed preferable from an environmental, health and safety perspective. The hazard properties are intrinsic to the chemical, which means that regardless of the way that a chemical is used, these characteristics do not change. The goal of the substitution processes is to advance inherently safer chemicals and products, consistent with the principles of green chemistry.

Table 1. Perchloroethylene hazards profile.

Perchloroethylene		
Chemical name (IUPAC)	Tetrachloroethene	
Identification number	CAS number: 127-18-4 EC number: 204-825-9	
Trivial names	Tetrachloroethylene, Perchloroethylene, Perchloroethene,PCE, Perc., Per, 1,1,2,2-tetrachloroethylene,Ethylenetetrachloride,Perstabil®,Ankilostin®,Didakene®,Perclene®,Dowper®,Perklone®, Antisol1, Carbonbichloride, Didakene, Dow-per, ENT 1860, Fedal-Un, NCI-C04580, Nema,Perawin,Perclene,Percosolve, Perk,Perklone,Persec, RCRAWasteNumber U210, Tetlen, Tetracap,Tetraleno,Tetralex,Tetravec,Tetroguer,Tetropil	
Substance function	Chlorinated hydrocarbon solvent	
Classification	67/548/EEC classification Carc. Cat. 3; R40 - N; R51-53 R40 : Limited evidence of a carcinogenic effect. R51/53 : Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Regulation 1272/2008 (CLP) classification: Carc Cat. 2 H351: Suspected of causing cancer Click for labelling H411: Toxic to aquatic life with long lasting effects	Source: ESIS and GHS

	Properties	Source of information
Physical Hazards		
Explosivity	Notexplosive	http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf
Flammability	Notflammable	http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf
Oxidizing	not an oxidising agent and is stable at normal temperatures	http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf
Otherproperties of reactivity	When exposed to light and air (oxygen), tetrachloroethylene will slowly oxidise to trichloroacetyl chloride and phosgene at ambient temperatures.	http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf
Human HealthHazards		
Acutetoxicity		
Acuteeffects	Sigle exposure can cause signs of CNS depression, including dizziness, headaches, confusion, sleepiness, nausea, speaking and walking difficulty. Massive exposure may cause unconsciousness, proteinuria and hematuria.	TOXNET http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~bYxE2x:1
Skin or eye corrosion / irritation	Irritates eyes, nose and throat Prolonged exposure may cause skin irritation	http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~bYxE2x:1
Chronic toxicity		
Category 1 (nervous system, liver, respiratory organs, kidneys)		http://www.echemportal.org/echemportal/substancesearch/substancesearchresult.action?view=flat&queryTicket=SUBQ9xf&pageID=9&exactName=Tetrachloroethylene
Carcinogenicity	Probably carcinogenic to humans (IARC 2A)	SUBSPORT SDSC
Mutagenicity	Not classified	http://www.echemportal.org/echemportal/substancesearch/substancesearchresult.action?view=flat&queryTicket=SUBQ9xf&pageID=9&exactName=Tetrachloroethylene

	Properties	Source of information
Reproductive toxicity (including developmental toxicity)	Category 2: Based on the description in CERI-NITE Hazard Assessment No.65 (2005), ACGIH (7th, 2001), ATSDR (1997) and NICNAS (2001): Adverse effects are observed in the embryonic development of rats and mice. Tetrachloroethylene is able to transport across the placenta to the fetuses of pregnant women who have been highly exposed. Tetrachloroethylene has been found in breast milk of mothers exposed to the chemical.	http://www.echemportal.org/echemportal/substancesearch/substancesearchresult.action?view=flat&queryTicket=SUBQ9xf&pageID=9&exactName=Tetrachloroethylene http://www.turi.org/library/turi_publications/five_chemicals_study/final_report/chapter_5_perchloroethylene#5.1.2
Endocrine disruption	Category 2: Potential for endocrine disruption.	http://ec.europa.eu/environment/endocrine/documents/final_report_2007.pdf
Respiratory or skin sensitization	Skin Sens. 1H317: May cause an allergic skin reaction.	tetrachloroethylene - self classification (EU CLP)
Neurotoxicity	Category 1 (nervous system, liver, respiratory organs, kidneys)	http://www.echemportal.org/echemportal/substancesearch/substancesearchresult.action?view=flat&queryTicket=SUBQ9xf&pageID=9&exactName=Tetrachloroethylene
Immune system toxicity		
Systemic Toxicity	Liver and kidney toxicity	TOXNET http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~bYxE2x:1
Toxic metabolites	S-(1,2,2-trichlorovinyl)glutathione (TCVG) S-(1,2,2-trichlorovinyl)-L-cysteine (TCVC) trichloroethanol (TCOH) trichloroacetic acid (TCA)	TOXNET http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~bYxE2x:1
EnvironmentalHazards		
Acute/chronic aquatic toxicity	Aquatic Chronic 2H411: Toxic to aquatic life with long lasting effects	tetrachloroethylene - according to Regulation No 1272/2008 Annex VI tetrachloroethylene - self classification (EU CLP)
Bioaccumulation	Tetrachlroethylene has a low potential for bioaccumulation based upon measured levels in fish (BCF 40-50) and Log Kow of 2.53.	http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf

	Properties	Source of information
Persistence	Persistent substance: Half life (days): Water :60; Soil: 120; Sediment:540; Air:96	PBT profiler http://www.pbtprofiler.net
Greenhouse gas formation potential	Tetrachloroethene is not expected to contribute significantly to global warming	http://www.inchem.org/documents/cicads/cicads/cicad68.htm#5.3
Ozone-depletion potential	Expert working groups on ozone depletion (WMO, 1991) consider the contribution that tetrachloroethylene makes to ozone depletion to be negligible when compared to other ozone depleting chemicals such as CFCs, HCFCs, carbon tetrachloride and 1,1,1-trichloroethane.	http://ecb.jrc.ec.europa.eu/DOCUMENTS/Existing-Chemicals/RISK_ASSESSMENT/DRAFT/R021_0712_env_hh.pdf
Monitoring – has the substance been found in human or environmental samples?	Tetrachloroethylene has been detected in sediment, outdoor 8urban and rural) and indoor air, water, food, algae, fish, wild animals and breast milk.	TOXNET http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~bYxE2x:1

2. Identify functions and uses

Several European countries consider PER as a priority substance to be restricted due to its hazardous properties. The USA considers that PER is a substance of most immediate concern for emergency planning and response, and Canada identifies PER as a substances that should be assessed on a priority basis.

Due to its toxic and hazardous properties, PER has also been included in NGO and Trade Union lists of priority substances for elimination or substitution and several companies include Per in their lists of restricted substances[1].

2.1. Production and use

Production of tetrachloroethenehas steadily declined in the USA and Europe since the 1980s. Production in the USA in 1981 was estimated to be about 350,000 tonnes buthad fallen to 169,000 tonnes by 1998. Production in Europe has fallen from 164,000tonnes in 1994 to 44,000 tonnes in 2004[2].

1 http://www.subsport.eu/list-of-lists-database

2 WHO. Concise International Chemical Assessment Document 68 TETRACHLOROETHENE, WHO, Geneva, 2006. http://www.who.int/ipcs/publications/cicad/cicad68.pdf

Currently, tetrachloroethene is produced mainly byoxychlorination, chlorination, and/or dehydrochlorinationreactions of hydrocarbons or chlorinated hydrocarbons,most commonly the chlorination of propylene andthe oxychlorination of 1,2-dichloroethane.

Tetrachloroethene is used mainly as a solvent fordry cleaning and as a chemical intermediate, with additionaluse for vapour degreasing in metal cleaning. It isalso used for processing and finishing in the textileindustry, as an extraction solvent, as an anthelmintic, asa heat exchange fluid, in grain fumigation, and in themanufacture of fluorocarbons.

The major uses of tetrachloroethylene in Europe are as a chemical intermediate and as dry cleaningsolvent. Other uses include metal cleaning and extraction processes. Some minor uses havebeen reported, including itsuse as a textile scouring solvent, fumigant, stain remover,paint remover and heat transfer media ingredient. Table 2 gives an estimation of the amountused in each application in 1994[3].

Table 2. Breakdown of perchloroethylene use (1994)

Application	Percentage of production volume	Percentage of Sales	Tonnes per annum
Dry cleaning agent	38	80	62,400
Metal cleaningagent	9	18	14,000
Chemicalintermediate	18		30,000
Exports	34		56,000
Other	1	2	1,600
Total	100	100	164,000

The production decline in Europe is considered to be due to the decline (with the exception of Spain) in the amount of dry cleaning being carried out in the EU, as water-washable textiles have become more common and the use of more efficient dry cleaning machines has increased, as well as solvent re-cycling, improved housekeeping and the use of enclosed systems.
Perchloroethylene(PER) has stabilized its production in Europe on its 2008 value of 44,00 tonnes per year. The use of PER as a substitue for Trichlorethylene could generate some future market shares[4].

PER is used in Europe (decreasing order of share)[5]:

1. as starting raw material to produce fluorinated hydrocarbons and fluorinated polymers, other fluorinated derivatives like trifluoroacidic acid and TRI (through reduction).
2. as solvent mainly for professional dry cleaning, in industrial textile treatment and for surface (mainly metal) cleaning.
3. as reactant for catalyst regeneration in the petrol industry.

[3]European Chemicals Bureau (ECB). European Union Risk Assessment Report tetrachloroethylene Part I – environment. Series: 1st Priority List Volume: 57
http://esis.jrc.ec.europa.eu/doc/risk_assessment/REPORT/tetraENVreport021.pdf
[4]http://www.process-worldwide.com/management/markets_industries/articles/321982/

[5]ECSA percloroethylene Facts and Figures. http://www.eurochlor.org/chlorinated-solvents-%28ecsa%29/facts-figures/perchloroethylene.asp

Table 3. Overview of perchloroethylene uses.

Sector	Use	Source of information
S96.0.1 Washing and (dry-)cleaning of textile and fur products	Solvent used in commercial and industrial dry cleaning.	EU RAR[6]
	Spot stain remover	
C13.1.0. Preparation and spinning of textile fibres	Removal of lubricants during the production of textile fabrics.	EU RAR
C13.3.0 Finishing of textiles	Water repellents for garments	ICIS[7]
C19.1.0. Manufacture of coke oven products	Process solvent for desulfurizing coal	TURI[8]
C20.1.1 Manufacture of industrial gases	Chemical intermediate in the production of :HCFCs 123 and 124 HFC 125. H(C)FCs 113, 115, 116, 121, 122.	EU RAR
C20.1.1 Manufacture of industrial gases	Raw material in the manufacture of hydrofluorocarbon (HFC) 134a, an alternative to chlorofluorocarbon (CFC) refrigerants.	EU RAR
C20.2.0 Manufacture of pesticides and other agrochemical products	Biocide for the treatment of textiles against insects in museums and buildings of cultural, artistic and historical interest	EU RAR
C20.3.0 Manufacture of paints, varnishes and similar coatings, printing ink and mastics.	Paint remover	EU RAR
C20.5.2. Manufacture of glues	Adhesive formulations	TURI
C20.5.9 Manufacture of other chemical products n.e.c.	As a carrier solvent for silicones	ICIS
C22.2.1. Manufacture of plastic plates, sheets, tubes and profiles	Tetrachloroethylene is used in a mixture with n-butanol to wash away the developer in the preparation of photo-polymer plates	EU RAR
C25.6.1 Treatment and coating of metals	Metal degreasing	EU RAR
C26.1.1. Manufacture of electronic components	Insulating fluid in some electrical transformers as a substitute for polychlorinated biphenyls (PCBs).	ICIS
C28.2.5. Manufacture of non cooling and ventilation equipment	In heat transfer media	EU RAR

[6] http://ecb.jrc.ec.europa.eu/risk-assessment/REPORT/tetraENVreport021.pdf

[7] http://www.icis.com/v2/chemicals/9076131/perchloroethylene/uses.html

[8] http://www.turi.org/library/turi_publications/five_chemicals_study/final_report/chapter_5_perchloroethylene#5.1.3

Sector	Use	Source of information
T97.0.0 Activities of households as employers of domestic personnel N81.2 Cleaning activities	Household rug & upholstery cleaners Oven cleaners	TURI

2.2. Prioritization of uses

Prioritization factors considered by SUBSPORT's Specific Substances Alternatives Assessments Protocol include the following, not ranked in any particular order:

- Prioritize uses that represent largest volume uses of the chemical of concern.
- Prioritize uses where evidence indicates potential elevated exposure to workers, the environment or consumers of final products (due to the dispersive nature/use? of the chemical).
- Prioritize uses in products that may affect a sensitive population, such as children
- Prioritize uses of greatest regulatory or market interest for substitution.
- Prioritize "chemically-intensive" uses, where other chemicals of potential concern are used in conjunction with the chemical identified for substitution.

Environmental exposure data to PER from different uses in Europe is summarized in table 4[9]. Dry cleaning and metal cleaning compromise more than 90% of continental and regional environmental releases of PER to air and water. Both uses imply the exposure of thousands of workers in Europe and through dry cleaning, also consumers are also exposed to PER. Therefore, the use that will be prioritized for further assessing its alternatives is dry cleaning.

Table 4.Summary of environmental releases of PER (kg/day).

Scenario	Continental		Regional		Local	
	Air	Water	Air	Water	Air	Water
Production and use as a chemical intermediate*	35	0.66	602	0.67	733	0.81
Drycleaning	110,948	51	28,244	5.6	15.5	0.003
Metal cleaning	31,068	346	3,452	38	42	0.48
Landfill	7,397		822			
Total	149,448	398	33,120	44		

* Regional and continental releases adjusted to 365 days per year

[9] http://ecb.jrc.ec.europa.eu/risk-assessment/REPORT/tetraENVreport021.pdf

3. Preliminary identification of alternatives

Table 5. Alternatives identified for main uses of PER.

Use	Identified Alternatives
Solvent used in commercial and industrial dry cleaning.	HCS (hydrocarbon) siloxane D5 dibutoxymethane (SolvonK4) glycol ether (Rynex) D5 and hydrocarbon (iPura processes) liquid CO2 wet cleaning Ref[10]
Spot stain remover	
Removal of lubricants during the production of textile fabrics.	Polyether/polyester or polyether/polycarbonates Special polyolesters Special steric hindered fatty acid esters. Ref.[11]
Water repellents for garments	Perfluorinated Compounds (PFCs) Coated, Breathable Membranes - Fabrics Created with a PU Coating and a Membrane construction to Waterproof them. Emulsion of water, acetic acid and zirconium acetate (Nikwax TX) Ref[12]
Process solvent for desulfurizing coal	Physical cleaning: -separation using Speciif Gravity Difference - Separation using Surface properties - Magnetic and electrostatic separation Biological cleaning: - Enzymatic coal desulfurization Ref[13]
Paint remover	terpene solvents N-methylpyrrolidone dibasic esters dimethylformamide Nitromethane Dimethyl sulfoxide Heat guns mineral washing soda Ref[14,15]

[10] http://drycleanwarehouseinc.com/the-textile-cleaning-industrys-evolving-technology-and-solvents/ and ÜbersichtzuReinigungsverfahren und Lösemitteln in der Textilreinigung http://www.dtv-bonn.de/index.php?newsid=539&topnav=1&rubrik=2&highlight=2

[11] Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques for the Textiles Industry, July 2003. http://eippcb.jrc.es/reference/BREF/txt_bref_0703.pdf

[12] Guide to waterproofing http://www.gooutdoors.co.uk/expert-advice/guide-to-waterproofing-

[13] Ohtsuka Y Desulfurization of Coal.Coal, Oil Shale, Natural Bitumen, heavy Oil and Peat.Vol 1. http://www.eolss.net

[14] http://en.wikipedia.org/wiki/Paint_stripper

[15] http://www.care2.com/greenliving/paint-strippers.html

Use	Identified Alternatives	
Metal degreasing	Alkaline agents Acid agents Neutral agents Hydrocarbons Aromatic solvents Halogenated solvents Semi-aqueous cleaners Fatty acid esters Synthetic esters Alcohols Ketones Glycoles Glycol ethers	Terpenes Enzymes CO2 (ice pellets or carbon dioxide snow) Blasting / CO2 dry ice blasting Laser Ablation Plasma Mechanical cleaning Biocleaning Electrolytic cleaning Salt bathcleaning Ref[16]
Tetrachloroethylene is used in a mixture with n-butanol to wash away the developer in the preparation of photo-polymer plates	Terpenes[17] P-Flex PhotopolymerPlate[18]	
Film cleaning and copying	Ultrasonic Film Cleaner[19]	
Insulating fluid in some electrical transformers as a substitute for polychlorinated biphenyls (PCBs) and heat transfer media.	Siliconeoil[20]	

3.1. Preliminary identification of alternatives to PER used in dry cleaning.

3.1.1. Alternative solvents

Properties of solvents to be considered suitable alternatives for dry cleaning include evaporation rate and ease of purification through distillation. They should also not cause fabric to fade shrink, weaken or bleed color and should be compatible with detergents[21].
Several solvents are used as alternatives to PER as shown in Table 6.

Table 6. Alternative dry cleaning solvents.

Name	Main ingredients
Hydrocarbons	Naphtas(CAS 64742-48-9)
Siloxane D5 (GreenEarth)	Decamethylcyclopentasiloxane (CAS 541-02-6)
Dibutoxymethane (SolvonK4)	Dibutoxymethane (CAS 2568-90-3)
Glycol ether (Rynex)	Dipropylene Glycol t-Butyl Ether (EINECS/ELINCS 422-300-4) (CAS 132739-31-2)
D5 and hydrocarbon (iPura processes)	Naphtas(CAS 64742-48-9) Decamethylcyclopentasiloxane (CAS 541-02-6)

[16] http://www.cleantool.org
[17] http://www.patentgenius.com/patent/4847182.html
[18] http://www.p-flex.com/EN/product.php
[19] http://www.rtico.com/cf9200/
[20] http://www.lauda.de/
[21] TURI (2006).Five Chemicals Alternatives Assessment Study. Chapter 5. Perchloroethylene.

3.1.2. Alternative processes

Liquid CO2
Carbon dioxide textile cleaning works by pressurizing carbon dioxide into liquid and then injecting the carbon dioxide with a special detergent. While this method is not necessarily recommended for heavily soiled clothes, garments that are only lightly soiled will come out of the process crisp, cool, and clean. Carbon dioxide is non-toxic, and textile cleaners that use this form of cleaning run the carbon dioxide on a closed system in order to prevent its release into the atmosphere. Several companies distribute this technology.

Wetcleaning
Wet cleaning uses high-tech detergents, degreasers, as well as conditioners that can utilize water as a solvent without causing the shrinking of clothes or the leeching of colors. Washers and dryers are computerized, and many of the health problems caused by PER and other solvents are eliminated. Specialized finishing equipment is also required. Some textile cleaners use a wet cleaning technique called icy water that uses cold water to clean clothes and allows textiles to be fully dried in a dryer. Several companies distribute these technologies.

4. Screening out regrettable substitutes for dry cleaning

Table 7Screening of alternatives for dry cleaning with SUBSPORT criteria.

Chemicalalternatives	Ingredients	SDSC	Hazardousproperties
Hydrocarbons	Naphtas(CAS 64742-48-9)	Naftas are included in the SDSC because it is classified as a carcinogen CLP H350	R45 : May cause cancer. R46 : May cause heritable genetic damage.
Siloxane D5 (GreenEarth)	Decamethylcyclopentasiloxane (CAS 541-02-6)	Not listed in SDSC	No harmonized classification. ECHA Notified classification and labelling according to CLP criteria: Aquatic Chronic 4 H413, Eye Irritant 2 H319, acute toxicity 3 H331, skin irritant 22 H315 A screening assessment carried out by Environment Canada and Health Canada establishes that it is Carcinogen, persistent and with potential to bioacumulate[22]
Dibutoxymethane (SolvonK4)	Dibutoxymethane (CAS 2568-90-3)	Not listed in SDSC	No harmonized classification. ECHA Notified classification and labelling according to CLP criteria:Flam. Liq. 3H226, Skin Irrit. 2H315, Aquatic Chronic 3 H412.

[22] **Screening Assessment for The Challenge Decamethylcyclopentasiloxane (D5) CAS 541-02-6.** Environment Canada. &Health Canada. November 2008. http://www.ec.gc.ca/substances/ese/eng/challenge/batch2/batch2_541-02-6.cfm

Glycol ether (Rynex)	Dipropylene Glycol t-Butyl Ether (CAS 132739-31-2)	Not listed in SDSC	No harmonized classification. ECHA Notified classification and labelling according to CLP criteria: Eye Irrit. 2: H319. Skin Irrit.2: H315
D5 and hydrocarbon(iPura processes)	Naphtas (CAS 64742-48-9) Decamethylcyclopentasiloxane (CAS 541-02-6)	Naftas are included in the SDSC because it is classified as a carcinogen CLP H350	R45 : May cause cancer. R46 : May cause heritable genetic damage. No harmonized classification. ECHA Notified classification and labelling according to CLP criteria: Aquatic Chronic 4 H413, Eye Irritant 2 H319, acute toxicity 3 H331, skin irritant 22 H315
Alternative processes			
Wetcleaning	Water Detergents		
Carbon dioxide textile cleaning	CO2 (CAS: 124-38-9)	Not listed in SDSC	RISCTOX: Ototoxicant Substance listed in the list of the Kyoto Protocol

5. Characterizing alternatives

Hydrocarbons are the only alternatives that don't pass SUBSPORT criteria. Siloxane is carcinogen, persistent and has potential to bioackumulate, therefore it is not considered a safer alternative for PER and is also screened out.
Hazard characteristics of the remaining alternatives, as well as their technical and economic feasibility will be discussed in this section.

5.1. Hazard characteristics of alternatives

Table 8. Hazard characteristics ofDibutoxymethane (CAS 2568-90-3)

	Properties	Source of information
Physical Hazards		
Explosivity	Data lacking	ECHAC&L Inventory
Flammability	Flam. Liq. 3 H226,	ECHAC&L Inventory
Oxidizing	Data lacking	ECHAC&L Inventory
Otherproperties of reactivity	Data lacking	ECHAC&L Inventory

	Properties	Source of information
Human HealthHazards		
Acutetoxicity		
Acute toxicity	Data lacking	ECHA C&LInventory
Skin or eye corrosion / irritation	Skin Irrit. 2 H315	ECHAC&L Inventory
Chronic toxicity		
Carcinogenicity	Not listed in IARC andCLP	CLP, IARC
Mutagenicity	Not listed	CLP
Reproductive toxicity (including developmental toxicity)	Not listed	CLP
Endocrine disruption	Not listed	OECD, EU Endocrine disruptordatabase, SIN list
Respiratory or skin sensitization	Data lacking	ECHA Registration
Neurotoxicity	Not listed	Vela et al.
Immune system toxicity	Data lacking	ECHA Registration
SystemicToxicity	Data lacking	ECHA Registration
Toxicmetabolites	Data lacking	ECHA Registration
Acute/chronicaquatictoxicity	Aquatic Chronic 3 H412	ECHAC&L Inventory
Bioaccumulation	Data lacking	HSDB/TOXNET
Persistence	Data lacking	HSDB/TOXNET
Greenhouse gas formationpotential	Not listed	ICCP
Ozone-depletionpotential	Not listed	ICCP
Monitoring – has the substance been found in human or environmental samples?	Data lacking	HSDB/TOXNET

Table 9. Hazard characteristics of Dipropylene Glycol t-Butyl Ether (CAS 132739-31-2)

	Properties	Source of information
Physical Hazards		
Explosivity	Data lacking	ECHAC&L Inventory
Flammability	Data lacking	ECHAC&L Inventory
Oxidizing	Data lacking	ECHAC&L Inventory
Otherproperties of reactivity	Data lacking	ECHAC&L Inventory
Human HealthHazards		
Acutetoxicity		
Acute toxicity	Data lacking	ECHA C&LInventory
Skin or eye corrosion / irritation	Eye Irrit. 2: H319. Skin Irrit.2: H315	ECHAC&L Inventory

	Properties	Source of information
Chronic toxicity		
Carcinogenicity	Not listed in IARC andCLP	CLP, IARC
Mutagenicity	Not listed	CLP
Reproductive toxicity (including developmental toxicity)	Not listed	CLP
Endocrine disruption	Not listed	OECD, EU Endocrine disruptordatabase, SIN list
Respiratory or skin sensitization	Data lacking	ECHA Registration
Neurotoxicity	Not listed	Vela et al.
Immune system toxicity	Data lacking	ECHA Registration
SystemicToxicity	Data lacking	ECHA Registration
Toxicmetabolites	Data lacking	ECHA Registration
Acute/chronicaquatictoxicity	Data lacking	ECHAC&L Inventory
Bioaccumulation	Data lacking	HSDB/TOXNET
Persistence	Data lacking	HSDB/TOXNET
Greenhouse gas formationpotential	Not listed	ICCP
Ozone-depletionpotential	Not listed	ICCP
Monitoring – has the substance been found in human or environmental samples?	Data lacking	HSDB/TOXNET

It is not possible to establish an informed hazards profile of these two alternative solvents given the lack of data on most of the toxicological and ecotoxicological endpoints.

5.2 Technical feasibility of alternatives

All remaining alternatives, dibutoxymethane (Solvon K4), glycol ether (Rynex), wet cleaning and CO2 cleaning are available in the market and in use in dry cleaning shops around the world. Several studies carried out in the US by the Institute for Research and Technical Assistance[23,24] and the Toxics Use Reduction Institute[25], as well as in Europe, by the Dutch technical center for the textile care industry (TKT)[26] have described and compared the technical performance of these alternatives.

The European study, published by the International Committee of Textile Care (CINET) tested the alternatives by cleaning a mix of newly purchased garments and fabrics, each cleaned three times at drycleaning plants during regular working hours along with normal cleaning loads from customers. The garments were examined for shrinkage, pilling, stain removal and graying after cleaning.

[23] Michael Morris and Katy Wolf (2005). Hydrocarbon Technology Alternatives to Perchloroethylene for Dry Cleaning. Prepared for: Cal/EPA's Department of Toxic Substances Control. Institute for Research and Technical Assistance. http://www.irta.us/Hydrocarbon%20Report.pdf

[24] Michael Morris and Katy Wolf (2006). ASSESSMENT, DEVELOPMENT AND DEMONSTRATION OF ALTERNATIVES FOR FIVE EMERGING SOLVENTS. Institute for Research and Technical Assistance.

[25] TURI (2006).Five Chemicals Alternatives Assessment Study.Chapter 5 Perchloroethylene. Massachusetts Toxics Use Reduction Institute.

[26] National Clothesline, August 2011, http://www.natclo.com/1108/cinet.htm

Stain removal was evaluated by solvent performance in the cleaning system; there was no pre- or post-spotting. The best results were obtained with PER followed by Rynex, SolvonK4, wetcleaning that scored the same as hydrocarbon and finally CO2

CO2 gave the best results for shrinkage after three cleaning cycles of test fabrics, showing less than 0.5 percent shrinkage for both wool and cotton. At the other end of the scale was wetcleaning, showing nearly 5 percent shrinkage on wool and 3.5 percent on cotton. The scores for the other processes were within a range of 0.5 percent to just over 1 percent on cottons and 0.5 percent to 2.5 percent on wools.
Shrinkage was evaluated directly after the cleaning process and without a finishing step which could affect results, particularly in wetcleaning.

Wool and cotton test fabrics were also examined for graying. The results were generally similar. The iPura hydrocarbon system showed the most graying; wetcleaning showed the least.

Wrinkling was reported as problematic only with the men's suit in the wetcleaning process. However, the wrinkles were "shallow" and easily removed in finishing.

Measurement of pilling and roughening were carried out by visual observations. Some pilling and roughening was seen on the sweater (100 percent wool) in the wetcleaning process. Due to the long drying times, a slight roughening was seen after the siloxane D5 process. With all other cleaning processes, no pilling was observed.
The study found no changes in color for all tested solvents and machine technologies. A decrease in shine was noted on the men's suit after wetcleaning.
Zippers were more difficult to open and close after cleaning in K4 and Rynex, the report noted.
Regarding odor, the report didn't find any scent detectable on the garments several days after cleaning and finishing the garments.

Glycol ether (Rynex) showed good results with respect to stain removal and graying, but somewhat more graying than with PER and hydrocarbon. The stain removal is very close to that of PER and shrinkage with test fabrics was comparable to PER and hydrocarbon. Hardly any pilling or roughening was seen on the test fabrics.

The study considers that CO2 needs strong improvement of detergents, as the stain removal and the graying, which is the job of the detergent, clearly lag behind the other technologies. With respect to the care aspect for the garments, liquid carbon dioxide gave excellent results.

Dibutoxymethane (Solvon K4) shows good stain removal almost on the same level as PER. The shrinkage with test fabrics was somewhat higher with cotton compared to PER and hydrocarbon but was lower with wool. The average shrinkage and graying of garments is comparable to that of PER and hydrocarbon.

Wetcleaning has seen many improvements in machine technology, drying technology and detergents over the last 20 years. Its stain removal shows a different profile compared to the non-polar solvents, yet the overall score is comparable to hydrocarbon. This means that different stains need pre- or post-spotting compared to the solvent-based technologies.

The report considers that Knitted woolen articles are not suited for wetcleaning due to shrinkage and pilling/roughening, although other articles that show somewhat more shrinkage directly after the cleaning process compared to solvent based cleaning can be resolved by the finishing process.

5.3 Economical feasibility of alternatives

A financial assessment of several alternatives to dry cleaning was conducted by the Massachusetts Toxic use Reduction Institute (TURI).
TURI collected data during site visits to dry cleaners using different alternatives.

Machine costs of alternative solvents were higher than machines using PER but wet cleaning equipment purchase price was lower than equipment using PER.

Alternative solvent cost was 25-200% higher than PER. Wet cleaning used more water and detergent but no solvent.

Spotting labour costs were all greater than when using PER.
Maintenance costs were higher for alternative solvents and for CO2, given the specialized maintenance of this last process. However, maintenance expenses for wet cleaning were 60% lower than for PER. Table 10 summarizes the costs of different dry cleaning alternatives reported in the TURI's study.

Table 10. Cost comparison of different dry cleaning processes in Massachusetts

Location	U7 Cleaners	C Cleaners	D Cleaners	L Cleaner	T Cleaners
Process	Wet Cleaning	HC	HC	SGE	VMS
Machine cost	Less	More	40% more	50% more	45% more
SolventCost	None	35% less	27% less	100% more	Same
Cost of detergent	100% more	100% more	Same	None	Same
Spottingagentcost	Same	Same	Same	67% less	Same
Spotting labor cost	50% more	30% more	60% more	20% more	60% more
Maintenance of equipment	60% less	40% more	60% more	None	Same
Overallcost of maintenance	60% less	40% more	60% more	None	Same
Water	Same	25% more	Same	None	Same
Gas	30% more	25% more	Same	Same	Same
Electricity	35% more	25% more	Same	Same	Same
Paperworkrequired per week		None		50% less	Less
Regulation-ComplianceCosts	Same	None	None	Same	
Licenses			None		$3,250
HazardousWasteDisposal	None	Same	Same	67% less	Same
HazardousWasteCosts	Same	Same	Same	Same	Same

6. Comparing PER free dry cleaning alternatives

Table 11. Comparison of dry cleaning alternatives

	Dibutoxymethane (Solvon K4)	Glycol ether (Rynex)	Wet cleaning	CO2 cleaning
Health aspects	PROS: no classified hazardous substances CONS: lack of information on most toxicological end points	PROS: no classified hazardous substances CONS: lack of information on most toxicological and ecotoxicological end points	PROS:no hazardous substances	PROS:no hazardous substances
Environmental aspect	PROS: CONS: Aquatic Chronic toxicity. Possible VOC emissions. Need for hazardous waste disposal Data lacking for most toxicological end points	PROS: no classified hazardous substances CONS: Possible VOC emissions. Need for hazardous waste disposal. Data lacking for most toxicological end points	PROS: no hazardous substance, no VOC emissions CONS: 35%increase in energy use	PROS: no hazardous substance, no VOC emissions CONS: Use of CO2, a green house gas
Performance aspects	PROS: Very good stain removal CONS:	PROS: best stain removal score of all alternative processes CONS:	PROS: Very good stain removal Least graying of all processes CONS : Worst shrinkage score of all alternative processes	PROS: best shrinkage score of all alternative processes CONS : Worst stain removal and shrinkage score of all alternative processes

	Dibutoxymethane (Solvon K4)	Glycol ether (Rynex)	Wet cleaning	CO2 cleaning
Cost aspects	PROS: CONS:	PROS:less spotting agent and paper work costs than PER CONS: more equipment and solvent cost	PROS: less waste disposal, equipment and maintenance costs than PER CONS: more detergent, gas and electricity costs than PER	

7. Summary and conclusion

Alternative processes (wet cleaning and CO2 cleaning) are safer than PER, as they have no important health risks. Alternative solvents seem to be less hazardous than PER, but it can not be concluded that they are safer as information on most toxicological an eco-toxicological endpoints of these substances is lacking.

Alternative solvents have similar environmental risks than PER. Wet cleaning consumes more energy than PER and CO2 cleaning uses a green house gas.

All considered alternatives have a good cleaning performance, although solvent alternatives remove stains better. Cost aspects are difficult to assess as the alternatives that have a higher solvent or waste cost, may show a lower cost in other factors.

Taking in account all these aspects wet cleaning appars to be the safest alternative to PER.

Examples of related case stories:

- 038-EN: Substitution of tetrachloroethylene used in dry clean systems by a professional wet clean system for the garment care industry
- 109-EN: Substitution of perchloroethylene in dry cleaners' shops by "wet cleaning" systems.