

Dry cleaners seeking safer alternatives to perc should consider the key environmental and human health criteria initially, and then apply the financial and technical criteria to their individual facilities to determine the best alternative for their facility.

## Summary

The alternatives assessed represent technically feasible alternatives to perc dry cleaning systems. The ability of individual facilities to justify the financial impact of switching to one of the alternatives varies. From a performance perspective, the client base (and its associated cleaning needs) and the skill of facility employees are important factors to consider when evaluating which alternative satisfies your individual facility needs. From a regulatory perspective, the alternatives assessed may require some additional attention, but in general, do not have restrictions that negate the feasibility of the alternative.

The primary differences between the various alternatives are associated with the environmental and human health and safety characteristics of the alternative systems. Overall the alternative solvents assessed exhibit less persistence, potential to bioaccumulate or aquatic toxicity in the environment than perc.

Perc is a probable human carcinogen with acute toxicity characteristics, negative impacts on the central nervous system and worker exposure concerns associated with its volatile nature. With the exception of nPB, the alternatives exhibit human health characteristics that are preferable to perc. **Because of toxicity concerns, nPB is not considered a safer alternative to perchloroethylene.**

In addition, toxicological data are lacking for some of the alternatives, particularly the new acetal-based system, making the current human health assessment incomplete. Because of these data gaps, it is possible that future analyses will identify additional impacts associated with the use of this or other systems.

A major concern that exists for many of the alternatives is flammability. Wet cleaning and carbon dioxide have no flammability concerns. The other alternatives are Class IIIA or IIIB combustible liquids, thus requiring specialized equipment to protect against fire or explosion.

## References

All information and references in this fact sheet are explained more fully in TURI Methods and Policy Report #27, 2012: Assessment of Alternatives to Perchloroethylene for Professional Garment Care (found in the Publications page on TURI's website: [www.turi.org](http://www.turi.org)).

The following endnotes relate to data found in the table.

## Endnotes

1. The primary solvent in wet cleaning is water. For the purposes of this table, the EH&S information provided applies to undiluted detergents and other additives common in wet cleaning processes, which are also common in other cleaning systems (See App. A in full report). These additives are present in amounts of 3 to 5% in wet cleaning, and are used in lesser amounts (~1%) in other systems.
2. The technical performance criteria considered in the full report include those indicated in the table as well as cleaning quality, detergents and performance boosters required, finishing requirements and waste management considerations.
3. Sinsheimer 2009.
4. The typical cost per pound cleaned values include capital, solvent, licensing, detergent, electricity, gas, spotting labor, finishing labor, and maintenance labor, maintenance of equipment, compliance, and hazardous waste disposal costs. (IRTA 2005)
5. Persistence criteria in each of the environmental media: Air [L≤2 days, H>2 days]; Sediment, Soil and Water [L<60 days, M≥60 days, H>180 days]. Low (L) is considered to be 'Not Persistent'.
6. Bioaccumulation criteria: Low (Not Bioaccumulative) <1,000, Mod (Bioaccumulative) ≥ 1,000.
7. Fish ChV (mg/l) Toxicity criteria: Low (Not Toxic) > 10mg/l or no effects at saturation, Mod (Toxic) <10 mg/l, High (Toxic) <0.1 mg/l.
8. This system is characterized as Low aquatic toxicity, with the exception of one constituent of the detergent package: Lanadol Aktiv, which contains 1-5% of Oleic acid Monoethanolamid, ethoxylated (CAS# 26027-37-2) and is predicted to be moderately toxic but readily biodegradable.
9. This value (based on the PBT Profiler model) differs from the Kreussler MSDS which states Solvon K4 is insoluble in water, and would therefore not reach a concentration in water sufficient to cause aquatic toxicity.
10. ACGIH (American Conference of Governmental Industrial Hygienists) TLV TWA, unless noted otherwise.
11. This value is for Stoddard Solvent; no established value for these specific substances.
12. Manufacturer's recommended value.
13. See endnote 15: 2-(2-butoxyethoxy) ethanol includes the central nervous system as a target organ.
14. At high concentrations (>6% in air), CO2 causes CNS effects, and at sufficient concentrations causes asphyxiation
15. Lanadol Avant contains 1-5% of 2-(2-butoxyethoxy) ethanol (CAS# 112-34-5), which can cause fertility impairment or teratogenesis (HAZMAP 2011). Concentration in washer is approximately 0.1%, which is below accepted de minimis.
16. Possible reproductive effects from minor β-isomer of propylene glycol ethers, which comprises ~1% of the substance. (INSERM 2006)
17. There are inherent difficulties with determining flash point of halogenated hydrocarbon liquids. Some test methods show no flash point for nPB, others show a flash point of 72°F (ECBI 2002). Under Massachusetts fire safety regulations, nPB is considered non-flammable, while the European Union has classified nPB as R11 (highly flammable). (EU 2009).
18. EPA National Ambient Air Quality Standards, see definition of VOC: [http://www.epa.gov/ttn/naaqs/ozone/ozonetech/def\\_voc.htm](http://www.epa.gov/ttn/naaqs/ozone/ozonetech/def_voc.htm)
19. Exempt from USEPA and MassDEP VOC regulations due to determination of negligible photochemical reactivity.
20. This assessment is for the overall system composition. One component of the cleaning package, Lanadol Avant contains 1-5% of 2-(2-butoxyethoxy) ethanol (CAS# 112-34-5), which is a VOC.
21. For wastewater disposal, facilities need to be aware of MassDEP regulations that require industrial wastewater, including that from professional wet cleaning or laundering processes, to be discharged to a public sewer or an appropriate holding tank for off-site transfer. Ground or surface water discharges can only occur with special permits.

## Alternatives to Perchloroethylene Used in Professional Garment Care

*Perchloroethylene (perc) was designated as a Higher Hazard Substance by the Massachusetts Toxics Use Reduction program in 2008. This fact sheet was developed by the Toxics Use Reduction Institute (TURI) to help Massachusetts professional garment care shop owners and their communities identify safer alternatives to perc for their dry cleaning operations.*

Perchloroethylene has been the standard dry cleaning solvent because of its effectiveness, ease of use, and relatively low cost. Unfortunately, improper use, storage and disposal of perc have resulted in widespread contamination of groundwater and soil at dry cleaning sites. In addition, exposure to perc is associated with a variety of adverse human health effects. Because of these impacts, perc is more strictly regulated today than in the past, and many cleaners are investigating alternatives for use in their operations.

Recent industry surveys estimate that from 50 to 70% of cleaners currently continue to use perc, while many US cleaners have switched to other solvents or cleaning methods. Even with these trends, Massachusetts dry cleaners reported using more than 450,000 pounds of perc and generating over 290,000 pounds of hazardous waste in 2010.

## About the Alternatives

TURI conducted an assessment of seven common alternatives to perc to find technically viable and environmentally preferred methods for professional garment cleaning. The alternatives evaluated include:

- **Professional Wet Cleaning:** a water-based process that uses computer-controlled washers and dryers along with biodegradable detergents and specialized finishing equipment to process delicate garments that would otherwise be dry cleaned. While this alternative is not new, the technology has evolved in the past 5-10 years, resulting in significantly improved performance.
- **Liquid Carbon Dioxide:** combining liquid carbon dioxide with specially formulated cleaning agents in a traditional basket-style machine under high pressure (700 psi). The higher cost of this alternative has limited its adoption.
- **High Flash Hydrocarbons:** a class of low-odor petroleum-based combustible dry cleaning solvents with a flash point

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greater than 140°F. This technology is the most widely used alternative to perc dry cleaning.

- **Acetal:** a halogen-free combustible solvent that came onto the US market in 2010 under the trade name SolvonK4, and appears to be gaining market share. Little information is available on the human health and environmental effects associated with this alternative.
- **Propylene Glycol Ethers:** a class of combustible petroleum solvents that were introduced in the late 1990s and can typically be used with a hydrocarbon machine after making minor modifications.
- **Cyclic Volatile Methyl Siloxane:** an odorless, combustible liquid that can be used in multi-solvent machines. The most common brand of this solvent is GreenEarth®.
- **N-Propyl Bromide (nPB):** considered a "drop-in" replacement for perc in existing dry cleaning equipment. However, nPB has toxicity concerns that make it an unacceptable alternative.

## Assessing the Alternatives

Criteria considered when assessing the alternatives include:

- Performance Impacts and Technical Feasibility
- Financial Considerations
- Environmental and Human Health Impacts
- Regulatory and Safety Implications

# Summary Table: Comparison of Perc and Seven Garment Cleaning Alternatives

The following table summarizes the comparison of the seven alternatives relative to perc, based on available data for key technical, economic, environmental, regulatory and human health criteria. Color coding has been used to indicate preferability of alternatives purely from an environmental and human health and safety perspective. The key environmental and human health criteria shown on this table are considered the most relevant for dry cleaning applications.

- Additional information and references are available in the full report.

Key Assessment Criteria		Perc (reference)	Wet Cleaning <sup>1</sup>	Carbon Dioxide	High Flashpoint Hydrocarbons	Acetal	Propylene Glycol Ethers	Siloxane	n Propyl Bromide
Common Trade Names / Manufacturers of Equipment or Solvents			Wascomat, Miele, Continental, HwaSung, AquaSolo	Cool Clean Technologies, Solvair®	DF2000™ Fluid, EcoSolv®, ShellSol D60, Caled Hydrocene	Solvon K4	Solvair®, Rynex 3®, Impress®, Gen-X®	Green Earth® D5 solvent	Drysolv®, Fabrisolv™ XL
	Solvent Chemical Identification [CAS#]	Perchloroethylene [127-18-4]	Solvent: Water Detergents: See full report <sup>1</sup>	Carbon Dioxide [124-38-9]	Naphtha (petroleum) hydro-treated heavy [64742-48-9]; C10-C13 Isoalkanes [68551-17-7]	1-(butoxy methoxy) butane (butylal) [2568-90-3]	dipropylene glycol tert-butyl ether, [132739-31-2]; di-propylene glycol n-butyl ether, [29911-28-2]	Decamethylcyclopenta siloxane (D5) [541-02-6]	N Propyl Bromide (nPB) [106-94-5]
Technical / Performance <sup>2</sup>	Cycle time (min)	45	20-40	35-45	60-75	60-65	>45	53-58	45
	Load capacity (lb)	50	20-75	60	35-90	40-90	43	55	50
Financial	Materials system may have difficulty with	Leather, suedes, beads, delicates	Leather, suede and fur	Triacetates, specially dyed acetates	Vinyl appliqués	Appliqués or decorations glued to fabric	None identified	None identified	Leather, suedes, beads, delicates
	Spotting requirements	Moderate	Low	High	Moderate	Low	Low	High	Low
Environmental	Equipment	\$40,000 - \$65,000	\$36,000 - \$61,000	\$100,000 - >\$150,000	\$38,000 - \$75,000	\$50,000 - \$100,000	\$56,000	\$30,500 - \$55,000	\$40,000 - \$60,000 or retrofit costs
	Chemical cost per gallon	\$17	\$0.007/gal (water); \$25-\$31/gal (detergent)	\$0.18/lb (CO <sub>2</sub> ); \$40/gal (detergent)	\$14-\$17	\$28-\$34	\$25-\$30	\$22-\$28	\$40-\$64
Human Health	Electricity usage <sup>3</sup> (kWh/100 lb)	26.6	9.3	30.9	35.5	Similar to hydrocarbon	Unavailable	54.2	Unavailable
	Typical cost per pound cleaned <sup>4</sup>	\$0.63-\$1.94 avg. \$1.02	\$0.57-\$1.32 avg. \$1.10	\$1.40	\$0.73-\$1.02 avg. \$0.88	Unavailable	\$1.14	\$1.08-\$2.33 avg. \$1.71	Unavailable
Safety	Persistence <sup>5</sup> (water, soil, sediment, air)	M (water), H (soil, sed, air)	L (water, soil, air), M (sed)	NA	L (water, soil, air), M (sed)	L (water, soil, air), M (sed)	L (water, soil, air), M (sed)	L (water, soil), H (sed, air)	L (water, soil), M (sed), H (air)
	Bioaccumulation <sup>6</sup>	Low	Low	NA	Moderate	Low	Low	Moderate	Low
Applicable Regulations	Aquatic Toxicity <sup>7</sup>	Moderate	Low to Moderate <sup>8</sup>	Low	High	Moderate <sup>9</sup>	Low	High	High
	Recommended Exposure limits <sup>10</sup>	25 ppm	NE	5000 ppm	100 ppm <sup>11</sup>	NE	NE	10 ppm <sup>12</sup>	10 ppm
Applicable Regulations	Central Nervous System Effects	Yes	No <sup>13</sup>	No <sup>14</sup>	Yes	No data available	Yes	Some evidence	Yes
	Carcinogenicity	IARC Probable human carcinogen	Not classified by IARC	Not classified by IARC	Not classified by IARC	Not classified by IARC	Not classified by IARC	Some evidence	Clear evidence in animal studies by NTP
Applicable Regulations	Reproductive / Developmental Toxicity	Yes	Negligible <sup>15</sup>	No data available	No data available	No data available	No <sup>16</sup>	Studies indicate concern	Yes
	Flash Point/ Flammability	NA / Not Flammable	NA / Not Flammable	NA / Not Flammable	140-145°F / Combustible liquid	144°F / Combustible liquid	160-212°F / Combustible liquid	171°F / Combustible liquid	NA <sup>17</sup>
Applicable Regulations	Clean Air Act Hazardous Air Pollutant (HAP)	Yes, HAP	No	No	No	No	No	No	No
	Clean Air Act NAAQS VOC <sup>18</sup>	No, Exempt <sup>19</sup>	No <sup>20</sup>	No	VOC	VOC	VOC	No, Exempt <sup>19</sup>	VOC
Applicable Regulations	Massachusetts regulated (TURA, ERP)	TURA Higher Hazard Substance, ERP	No	No	No	No	No	No	TURA
	Hazardous waste disposal required	Yes - Listed hazardous waste	No	No	Yes Waste Oil = Hazardous Waste in MA	No	No	No	No; monitor for residual perc if using retrofitted machine
Applicable Regulations	Wastewater discharge restrictions	No	Discharge to sewer or holding tank <sup>21</sup>	No	No	No	No	No	No

NA – Not Applicable; NE – Not Established