



# Alternatives to Perc for the Dry cleaning industry

## Solvent trends

- **K4:**

- There exist some 600-700 worldwide
  - 400 in the US
  - 50 in Germany
  - 50 in RUS

- **GreenEarth:**

- There exist some 1700 worldwide
  - 1000 in the US (incl. the textile manufacturing industry)
  - 120 in Germany
  - 230 in GB
  - 60 in RUS

- **Higlo:**

- Almost no machines except for NL and GB due to free of charge solvent incl. products for 1 year

- **Intense:**

- Almost no machines

We can clean that items with Softwash



# Solvents

| Brand name                             | DOWPER™ Pure Power | BÜFA TDC 2000 | Solvon K4           | GreenEarth                        | Higlo                      | Intense                    |
|--|--------------------|---------------|---------------------|-----------------------------------|----------------------------|----------------------------|
| Chemical discription                   | Perchloroethylene  | Hydrocarbon   | Dibutoxymethane     | Decamethylcyclo-pentasiloxan (D5) | Hydrocarbon + glycol ether | Hydrocarbon + N.N. solvent |
| Density (20 °C)                        | 1,62 g/ml          | 0,77 g/ml     | 0,83 g/ml           | 0,958 g/ml                        | 0,79 g/ml                  | 0,78 g/ml                  |
| Flash point                            | none               | 62 °C         | 62 °C               | 77,7 °C                           | 62                         | 63                         |
| Boiling point (1013 mbar)              | 121 °C             | 180 – 196 °C  | 180,5 °C            | 210 °C                            | 185                        |                            |
| KB-factor                              | 90                 | 32            | 72                  | 13                                | 45                         |                            |
| Solubility (solvent in water at 20 °C) | 160 mg/l           | < 20 mg/l     | 5400 mg/l           | 0,017 mg/l                        |                            |                            |
| Solubility (water in solvent at 20 °C) | 100 mg/l           | 50 mg/l       | 2400 mg/l           | very low                          |                            |                            |
| Evaporating no. (perc = 1)             | 1                  | 17,5          | 17,5                | ~ 50                              |                            |                            |
| Drying length*                         | 35 min.            | 28 min.       | 48 min. + cool down | 35 min.                           | 30 min.                    |                            |
| Relative stain removal* (hc = 100%)    | 220                | 100           | 110                 | 60                                |                            |                            |

# Perc

- **Pros perc:**

- One of the most studied solvents (used for more than 70 years in drycleaning)
- Best cleaning performance compared to all other solvents used in drycleaning
- Can cope with a huge amount of water/humidity → good cleaning of water soluble soilings
- 95% of all garments are labelled with the care label (P)
- It's non-flammable

- **Cons perc:**

- Environment and health issues
- In countries where perc isn't handled properly the future is unclear in a long term (e.g. US vs. Europe)
- Expensive waste disposal
- Many restrictions

# Perc

“People who are exposed to paint, glue or degreaser fumes at work may experience memory and thinking problems in retirement, decades after their exposure, according to a new study. Researchers assessed the workers' lifetime exposure to chlorinated solvents, petroleum solvents, and benzene, including the timing of last exposure and lifetime dosage”.

Source: <https://www.sciencedaily.com/releases/2014/05/140512213734.htm>

“It's frightening to hear that you can be breathing PERC and not even know it. The EPA says that, "Breathing PERC for short periods of time can adversely affect the human nervous system with symptoms ranging from dizziness, fatigue, headaches and sweating, to lack of coordination and unconsciousness. WHO, the World Health Organization, states that PERC is a "probable human carcinogen." U.S. Dept. of Health and Human Services adds that PERC damages liver and kidneys and affects reproductive organs. Though long-term health risks are not yet known, one way or another we all ingest it.”

Source: [http://www.naturalnews.com/023365\\_health\\_cleaning\\_dry.html](http://www.naturalnews.com/023365_health_cleaning_dry.html)

# Hydrocarbon Solvent (HC)

- **Pros hc:**

- Environmental friendly solvent
- Only existing solvent alternative to perc in terms of long term studies and care label (F)
- Colours don't fade and less degreasing of textiles → gentle textile care
- Availability and price

- **Cons hc:**

- Less cleaning power than perc (insufficient for industrial cleaning)
- Bacterial growth in case of poor machine maintenance → odour build up
- More spotting compared to perc if same cleaning result on retail garments is desired
- Cannot cope with a huge amount of water/humidity → limited cleaning of water soluble soilings

# Silicone solvent: GreenEarth

- **Pros silicone solvent:**

- Environmental friendly solvent
- No hazardous goods or hazardous substance
- Very good finishing properties
- Odour free
- Sorting of garments according to their colours is unproblematic
- Colours don't fade
- Garment manufacturers recommendation
- Landlords specified locations

- **Cons silicone solvent:**

- Insufficient cleaning power on dirty textiles
- License fee (brand protection)
- Longer drying time (10-20 min. compared to hydrocarbon) → higher energy consumption
- High solvent cost
- No existing care label (drycleaner is liable for damaged garments)
- Cannot cope with a huge amount of water/humidity → very limited cleaning of water soluble soilings

## Alternative solvents (dibutoxymethane/Solvon K4)

- **Pros dibutoxymethane:**

- Environmental friendly solvent
- No hazardous goods or hazardous substance
- Higher cleaning power than hydrocarbon but less cleaning power than perc (ideal alternative to perc for industrial cleaning)
- Can cope with a huge amount of water/humidity → good cleaning of water soluble soilings

- **Cons dibutoxymethane:**

- Limited suitable for delicate garments (damages of trimings/colour bleeding)
- No existing care label (drycleaner is liable for damaged garments)
- Very strong solvent odour; released also during the finishing or in storage packaging
- No existing long term studies in terms of health effects
- Oxidized in acidic environment to butanol (reduction of flash point) and formaldehyde
- Expensive solvent price (some 7 €/L)
- To minimize solvent odour an overdrying and purging of the garments is necessary → high energy consumption (sufficient drying takes 20-30 more minutes compared to hydrocarbon machines)
- Dependency on a monopolist for 10 years in case of patent approval.

## Alternative solvents (Higlo/Intense)

- **Pros Higlo:**

- More environmental friendly than perc (same like hc)

- **Cons Higlo:**

- Produces lots of dye runs
- Price of 7-8 €/kg
- More hc is solved in the water of the water separator (value exceeds to allowed concentration in Germany)
- No advantages compared to hc could be observed

## Background

Perchloroethylene – also known as perc or PCE (the full name perchloroethylene and the abbreviation ‘perc’ will be used interchangeably throughout the document) – is a solvent that is used for cleaning garments. It is the solvent that has been most often used by professional dry cleaners. Perc has been the standard dry cleaning solvent because of its effectiveness, ease of use, and relatively low cost. However, improper use, storage and disposal of perc have resulted in widespread contamination of groundwater and soil at dry cleaning sites. Exposure to perc is also associated with a variety of adverse human health effects, especially in dry cleaning workers. 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.

In 1999, the United States Environmental Protection Agency estimated that 85% of professional garment care facilities in the United States used perc as their main cleaning solvent. Based on more recent informal industry surveys in 2009 and 2012, the estimate is significantly lower – between 50 and 70% (AmD 2009, AmD 2012a). According to these surveys, many US cleaners have switched to other solvents or cleaning methods, and are also increasingly using wet cleaning to do a significant portion of their cleaning volume (AmD 2012b). 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 (MassDEP ERP).

## Health effects associated with Perc

‘Perc’ dry cleaning has been the accepted standard in the industry for close to 80 years. However, authorities have declared Perc harmful to health.

| Acute Effects (Short Term)  | Chronic Effects (Long Term)   | Cancer Hazards  |
|---|---|---|
| <ul style="list-style-type: none"> <li>• Single exposures can cause central nervous system effects (dizziness, headache, sleepiness, confusion, and nausea) and difficulty speaking or walking.</li> <li>• High-level exposure may cause vomiting, unconsciousness and death.</li> <li>• May cause skin irritation.</li> <li>• Irritating to the eyes, causing pain, redness and general inflammation.</li> <li>• Irritating to the nose and throat.</li> </ul> | <ul style="list-style-type: none"> <li>• Long-term exposure may cause liver and kidney damage.</li> <li>• Prolonged and repeated dermal exposure may cause dermatitis.</li> <li>• Increased health risks for people with pre-existing skin disorders and impaired renal or liver function.</li> <li>• Exposure may lead to developmental or reproductive toxicity.</li> <li>• Immune and hematologic system effects.</li> </ul> | <ul style="list-style-type: none"> <li>• IARC Group 2A, probable human carcinogen.</li> <li>• Reasonably anticipated to be a human carcinogen, (as evidenced by animal testing) by the US National Toxicology Program (NTP 2011a). Animal testing has linked high exposure to liver and kidney cancer as well as leukemia.</li> <li>• Studies of occupational exposure to perc in dry cleaning environments indicate an increased risk of kidney cancer for workers.</li> <li>• USEPA notes perc is “likely to be carcinogenic to humans” by all routes of exposure.</li> </ul> |

## Alternatives to Perc

The alternatives to perc that are assessed in this report were chosen based on national trends in dry cleaning, and on efforts under way in Massachusetts to find economically viable and environmentally preferred methods for professional garment cleaning.

The seven alternatives assessed are:

- Professional wet cleaning
- Liquid carbon dioxide
- High flash hydrocarbons
- Acetal
- Propylene glycol ethers
- Cyclic volatile methyl siloxane (D5)
- n-Propyl bromide (nPB)

## Performance of Wet cleaning

Performance of wet cleaning technology is optimized when proper wet cleaning equipment is used and when operators receive adequate training on the washer and dryer programs and tensioning equipment. Dimensional change (shrinking and stretching) of wet cleaned garments is only a concern if the cleaner does not use tensioning equipment or uses it incorrectly.

In February 2007, the Professional Wet Cleaning Demonstration Project completed through the Occidental College Urban and Environmental Policy Institute published their results of a study of seven cleaners who converted to dedicated wet cleaning sites. The study evaluated each cleaner's operations as a perc dry cleaner and used those results as a benchmark for comparison in the evaluation of each cleaner's operations as a professional wet cleaner. Five of the seven cleaners were able to professionally wet clean 99% of garments brought in by customers. Cleaners noted that their send-outs were due primarily to oil-based stains. Customer retention rates reported by demonstration site cleaners ranged between 98% and 100% (Sinsheimer 2007).

Between 2009 and 2011, the Massachusetts Toxics Use Reduction Institute assisted three Massachusetts dry cleaners in converting their operations to dedicated wet cleaning facilities. According to these facilities, once employees were fully trained, they experienced no increased send-outs, redos, or damage claims. These facilities have, however, sent out certain fur, leather, and suede items (Onasch 2010).

An additional performance metric for garment cleaning is the brightness of colors. It has been noted by cleaners in both California and Massachusetts that the wet cleaning process leads to brighter colors and whiter whites. This is likely due to the absence of recycled solvent, which can cause dinginess in the garments.

## Comparison of perc and 7 garments cleaning alternatives

| Key Assessment Criteria |  | Perc (reference)                  | Wet Cleaning                                   | Carbon Dioxide                                     | High Flash point Hydrocarbons  | Acetal                                   | Propylene Glycol Ethers | D5 Siloxane                    | n-Propyl Bromide                     |
|-------------------------|--|-----------------------------------|--|--|--------------------------------|--|-------------------------|--------------------------------|--------------------------------------|
| Technical Performance   | Cycle time                                 | 45 min                            | 20-40  | 35-45  | 60-75                          | 60-65                                    | >45                     | 53-58                          | 45                                   |
|                         | Load capacity                              | 50 lbs                            | 20-75  | 60   | 35-90                          | 40-90                                    | 43                      | 55                             | 50                                   |
|                         | 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                                  |
| Financial               | 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 cost |
|                         | 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                            |
|                         | Cost per pound cleaned (range and average) | \$0.63 - \$1.94<br>Avg: \$1.02    | \$0.57 - \$1.32<br>Avg: \$1.10                 | \$1.40   | \$0.73 - \$1.02<br>Avg: \$0.88 | Unavailable                              | \$1.14                  | \$1.08 - \$2.33<br>Avg: \$1.71 | Unavailable                          |
|                         | Electricity usage (kWh/100 lb)             | 26.6                              | 9.3  | 30.9   | 35.5                           | Similar to hydrocarbon                   | Unavailable             | 54.2                           | Unavailable                          |

# Comparison of perc and 7 garments cleaning alternatives

| Key Assessment Criteria |  | Perc (reference)              | Wet Cleaning                  | Carbon Dioxide         | High Flash point Hydro-carbons | Acetal                        | Propylene Glycol Ethers        | D5 Siloxane                       | n-Propyl Bromide                                   |
|-------------------------|--|-------------------------------|-------------------------------|------------------------|--------------------------------|-------------------------------|--------------------------------|-----------------------------------|--|
| Environmental           | Persistence (water, soil, sediment and/or 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), M (soil), H (sed, air) | L (water, soil), M (sed), H (air)                  |
|                         | Bioaccumulation                                | Low                           | Low                           | NA                     | Moderate                       | Low                           | Low                            | Moderate                          | Low  |
|                         | Aquatic toxicity                               | Moderate                      | Low to Moderate               | Low                    | High                           | Moderate                      | Low                            | High                              | High   |
| Human Health            | Recommended exposure limits                    | 25 ppm                        | NE                            | 5000 ppm               | 100 ppm                        | NE                            | NE                             | 10 ppm                            | 10 ppm   |
|                         | Central nervous system effects                 | Yes                           | No                            | No                     | Yes                            | No data available             | Yes                            | Some Evidence                     | Yes  |
|                         | Carcinogenicity                                | 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            |
|                         | Reproductive/developmental toxicity            | Yes                           | Negligible                    | No data available      | No data available              | No data available             | No                             | Studies indicate concern          | Yes  |
| Physical Safety         | 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 or 72°F (Flammability dependent on test method) |

# Comparison of perc and 7 garments cleaning alternatives

| Key Assessment Criteria |   | Perc (reference)                  | Wet Cleaning                       | Carbon Dioxide | High Flash point Hydro-carbons           | Acetal        | Propylene Glycol Ethers | D5 Siloxane   | n-Propyl Bromide   |
|-------------------------|---|-----------------------------------|------------------------------------|----------------|--|---------------|-------------------------|---------------|--|
| Applicable Regulatory   | Clean Air Act Hazardous Air Pollutant (HAP) | Yes, HAP                          | No                                 | No             | No                                       | No            | No                      | No            | No   |
|                         | Clean Air Act NAAQS VOC                     | No, Exempt                        | No                                 | No             | VOC                                      | VOC           | VOC                     | No, Exempt    | VOC  |
|                         | 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<br>Waste Oil = Hazardous Waste in MA | No            | No                      | No            | No; monitor for residual perc if using retrofitted machine |
|                         | Wastewater                                  | No wastewater                     | Discharge to sewer or holding tank | No wastewater  | No wastewater                            | No wastewater | No wastewater           | No wastewater | No wastewater  |

NA = Not applicable; NE = Not established

## Technical performance comparison

Key technical parameters for dry cleaners include cycle time, load capacity, and quality of cleaning. Additional considerations include pre-spotting and maintenance requirements, additional finishing or control equipment, equipment availability and vendor support, solvent odor issues, and waste management. Table 4 provides a summary of several technical performance assessment criteria important to dry cleaners.

Observations about the technical performance of the alternatives as summarized in Table 5 include:

- Wet cleaning cycle times are typically shorter than other systems – using a separate washer and dryer allows the two cycles to overlap, thereby saving time. Massachusetts cleaners that have converted to dedicated wet cleaning claim that they have significantly reduced their time at the spotting board. This is at least in part because most of the stains on clothes are well suited to removal by the water and detergent chemistries and technology. Wet cleaning exhibits better cleaning results for most fabric types, including the fact that clothes are less dingy than when cleaned with a recycled solvent. Massachusetts cleaners have stated that “whites are whiter and brights are brighter.”
- Hydrocarbon systems exhibit similar productivity to that of perc-based systems, and are said to produce a cleaner garment overall than some of the other solvent-based systems.

## Technical performance comparison

According to the manufacturer, the acetal system has a similar cycle time to perc, a wide range of load capacities and is able to clean a wide range of fabrics with minimal pretreatment.

Performance of nPB is expected to be similar to that of perc-based systems. It is reported that nPB systems would have similar difficulty with certain fabrics, and excessive color “bleed,” as perc-based systems.

Longer cycle times and smaller load capacities in propylene glycol ether and siloxane-based systems make them less productive than perc-based systems.

The spotting requirements for propylene glycol ether systems are reported to be less demanding than for perc. Propylene glycol ether systems are compatible with a wider range of fabrics and garments than perc-based systems.

Siloxane systems are reported to require more pre-spotting than perc systems.