



Review

Towards sustainable and safe apparel cleaning methods: A review

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ABSTRACT

Perchloroethylene (PERC) is a compound commonly used as a solvent in dry cleaning, despite its severe health and environmental impacts. In recent times chemicals such as hydrocarbons, GreenEarth[®], acetal and liquid carbon dioxide have emerged as less damaging substitutes for PERC, and an even more sustainable water-based wet cleaning process has been developed. We employed a systematic review approach to provide a comprehensive overview of the existing research evidence in the area of sustainable and safe apparel cleaning methods and care. Our review describes traditional professional dry cleaning methods, as well as those that utilise solvents other than PERC, and their ecological attributes. In addition, the new professional wet cleaning process is discussed. Finally, we address the health hazards of the various solvents used in dry cleaning and state-of-the-art solvent residue trace analysis techniques.

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1. Introduction

Professional dry cleaners have been using perchloroethylene (PERC) compound as a solvent since the 1950s. PERC has severe health and environmental impacts (Earnest et al., 2011). In recent times chemicals such as hydrocarbons, GreenEarth[®], acetal and liquid carbon dioxide (CO₂) have emerged as less damaging substitutes for PERC, and a promising water-based wet cleaning process has been developed (Santos, 2007). Wet cleaning of textiles is emerging as a viable alternative to dry cleaning due to its sustainability, lower health impacts on workers (Keoleian et al., 1997) due to its avoidance of toxic chemicals, and acceptable cleansing performance (Keoleian et al., 1998).

The toxicity of PERC and other dry cleaning methods has been thoroughly studied, and many jurisdictions have introduced measures to reduce chemical spills and exposure. In addition, researchers have raised concerns about the environmental impact of the energy used in laundering (Business for Social Responsibility, 2009; Collins and Aumônier, 2002; van der Velden et al., 2014). The percentage of the total energy usage of the apparel life cycle attributable to laundering is estimated to vary from 40% to more than 80%, depending on the fabrics involved (Business for Social Responsibility, 2009; Collins and Aumônier, 2002; van der Velden et al., 2014). Numerous factors influence energy usage, such as laundering method (e.g. dry cleaning or wet cleaning), frequency of laundering, and drying method (e.g. machine or line drying). Therefore, an understanding of the various laundering methods and their impacts on energy usage is vital to enable progress towards more sustainable and safe cleaning methods.

In this review, we sought to provide a comprehensive overview of existing dry-cleaning methods, their health and environmental impacts, alternative methods, and gaps in knowledge, in order to establish a foundation for further research into alternatives to PERC dry-cleaning and to inform decision-making and policy with respect to the commercial laundering industry. The review covers the professional dry cleaning methods commonly used for the aftercare of clothing items. Solvent alternatives to PERC are highlighted, along with their ecological attributes. In addition, the new professional wet cleaning process is discussed. Finally, we outline the health hazards of the various solvents used in dry cleaning as well as the state-of-the-art solvent residue trace analysis techniques.

2. Methodology

We applied a systematic review approach designed to provide a comprehensive overview of the existing research evidence in the area of sustainable and safe wool apparel cleaning methods and care.

To locate published studies, we conducted an extensive literature search using relevant electronic databases – principally Scopus and Web of Science, but also Google Scholar and EBSCOhost (including Textile Technology Complete databases). The review focused on commercial cleaning processes; the search strategy involved the keywords ‘dry cleaning’, ‘dry clean’, ‘wet cleaning’, ‘textile cleaning’, ‘garment cleaning’, ‘clothes’, ‘clothing cleaning’ and ‘washing’, combined with ‘environment’, ‘environmental’, and ‘sustainable’. The literature search was initially performed during June 2013 and updated in March 2016. References in relevant publications were examined for additional research to include in this review. The search imposed no restriction on publication date, but only papers written in English were included.

Retrieved studies were screened independently by the authors using titles of papers and abstracts. Once relevant studies were identified, the full publications were retrieved and reviewed

independently by the authors to determine their suitability. Any conflicts were resolved through further review conducted by the first author.

3. Fundamentals of professional dry cleaning

Dry cleaning is a process of cleaning garments with the help of chemical solvents, and is purported to have originated in France in 1825 when a worker in a dye factory spilled lamp oil (a hydrocarbon) on a soiled tablecloth and later noticed that the soiling had vanished (International Agency for Research on Cancer, 1995). The nascent dry-cleaning industry utilised hydrocarbon solvents such as kerosene, turpentine, petrol and benzene; all have the major disadvantage of extreme flammability, and unsurprisingly fires and explosions were common (Earnest et al., 2011).

Advances in chlorinated hydrocarbon production soon resulted in the development of non-flammable solvents for use in dry cleaning. Carbon tetrachloride (CCl₄) was preferred initially, but its toxicity and corrosive effect on metals, textiles and dyes were problematic, and through the 1950s it was gradually replaced by trichloroethylene (TCE) and tetrachloroethylene (or perchloroethylene – PERC). PERC (C₂Cl₄) is a volatile organic solvent; it is a colorless, clear and heavy liquid with a sweet odor (Ma et al., 2009; New York State Department of Health, 2013). PERC is used predominantly in dry-cleaning facilities to clean textile materials. It is also widely used in other industries to remove paint, degrease metals and clean wood (New York State Department of Health, 2013). An estimated 513,000 tonnes of PERC were used in western Europe, Japan and the USA in 1990, and an estimated 53% of world demand for PERC was for dry cleaning (International Agency for Research on Cancer, 1995). The USA has over 34,000 dry cleaners and an estimated 82% of them use PERC (U.S. Environmental Protection Agency, 2006). Contemporary dry-cleaning units can use 2.0–5.2 kg of PERC per 100 kg of clothing laundered (Keoleian et al., 1997). In New York State, approximately 1700 dry-cleaning establishments emit an estimated 118 tons (107 metric tonnes) of PERC to the atmosphere each year (New York State Pollution Prevention Institute, no date), which equates to 1754 tonnes per annum for the USA.¹

3.1. PERC dry-cleaning process

Modern clothing consists of many different fabrics and fiber compositions, and most are suitable for professional dry cleaning. Soiled garments are cleaned according to their aftercare instructions. They are inspected and sorted according to weight, color, finish and fabric, then visible stains are treated with chemicals at a ‘spotting station’ (depending on stain type, this can occur before or after cleaning). After sorting and pre-spotting, garments are ready for cleaning.

Cleaning is typically a three-step process involving washing, extracting and drying. Clothing is manually loaded into a machine, and detergent and water are added to the solvent during washing to assist soil and stain removal. Garments are agitated for minutes (or tens of minutes) according to the selected cleaning cycle. At the end of the cleaning cycle, the solvent is drained and garments are placed in a vacuum, dried and tumbled to remove residual solvent. After removal from the dryer, the garments are ironed (pressed) to remove creases and wrinkles. Any stubborn stains then undergo repeated spot-cleaning with chemical solvents.

Growing awareness of the negative health effects and

¹ Based on 82% of 34,000 dry-cleaning businesses using PERC in the USA (U.S. Environmental Protection Agency, 2006).

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