From Perchloroethylene Dry Cleaning to Professional Wet Cleaning: Making the Health and Business Case for Reducing Toxics

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Abstract **Increased regulatory oversight over the use of perchloroethylene (perc) in dry cleaning establishments due to health and environmental risks have prompted many dry cleaning facilities to seek substitutes. Among the most benign alternatives is professional wet cleaning. Yet, is wet cleaning viable from a business perspective? Using data from five dry cleaners that recently transitioned from perc to professional wet cleaning, this analysis reviews changes associated with cleaning performance, natural resource use, operations, labor, and associated costs. The financial assessment found that the average payback period related to the capital investments averaged 2.5 years and the average return on investment was 3.6 (using a discount rate of 5%). Higher financial returns were observed when cleaners kept their capital investments below $50,000. The performance evaluation found that garments cleaned with the wet cleaning technology came out as well as or better than with perc, especially as the cleaner became more familiar with the wet cleaning process. This analysis affirms the business case for wet cleaning, adding to the body of evidence that professional wet cleaning is not only environmentally preferable, but that it is also technically and financially feasible.**

Introduction

For over a hundred years, the dry cleaning industry has been reliant on the use of hazardous solvents. Despite its name, dry cleaning involves the use of liquid solvents to remove stains from fabrics. Since the 1950s, perchloroethylene (perc, also known as tetrachloroethylene) has been the dominant dry cleaning solvent in the U.S. (Doherty, 2000). In 2006, the U.S. Environmental Protection Agency (U.S. EPA) estimated that 28,000 dry cleaning operations across the U.S. still use perc—an estimate that remains current on their Web site today (U.S. EPA, 2016a)

Given the widespread use of perc, as well as fugitive and environmental emissions, there is considerable potential for human exposure among both workers and the general population. Perc contamination of groundwater and soil has become as widespread as the dry cleaning industry itself. In 2001, a report estimated that 75% of dry cleaning properties were contaminated primarily with perc, along with other dry cleaning solvents that have historically been used (Schmidt, DeZeeuw, Henning, & Trippler, 2001). Perc can be released into the environment during routine dry cleaning operations due to improper use, poor housekeeping practices, lack of maintenance and resulting malfunctioning equipment, and spills, as well as improper storage and disposal.

Over 30 years ago, evidence emerged regarding higher mortality rates from cancer among dry cleaning workers (Blair et al., 1990). In 2012, U.S. EPA classified perc as "likely to be a human carcinogen by all routes of exposure" and in 2014, the International Agency for Research on Cancer maintained its classification of perc as a "probable carcinogen" (U.S. EPA, 2016b; World Health Organization [WHO], 2014).

Studies most consistently demonstrate elevated risks of bladder cancer with perc exposure, although elevated risks of non-Hodgkin lymphoma, kidney cancer, and multiple myeloma have also been observed (Guyton et al., 2014; WHO, 2014). Perc also causes liver, kidney, and central nervous system damage with long-term exposure, as well as neurological effects including vision disturbances and decreased reaction time with short-term exposure (Guyton et al., 2014). While workers are at greatest risk of exposure and associated health effects, several studies have documented health outcomes in the general population associated with ambient exposure to perc from residences that were colocated in the same building as dry cleaners (Ma, Lessner, Schreiber, & Carpenter, 2009; Schreiber et al., 2002).

These recognized public health and environmental risks have resulted in increased regulatory oversight and have prompted many dry cleaning firms to seek substitutes. In 2006, the U.S. EPA strengthened the air toxics requirements for dry cleaners using perc (U.S. EPA, 2006). The rule includes a phase out of perc used at dry cleaners located in residential buildings by 2020, along with

TABLE **1**

Facility Demographics and Wet Cleaning Capital Investments

Facility Name	Silver Hanger	Ace	King & Queen	AB	KMK
Square footage	1,300	2,300	1,700	1,600	2,000
Full-time employees	7	4.5	3	3	6
Year of intervention	2008	2010	2011	2012	2012
Washer	$13,327	$14,114	$41,045[a]	$7,218	$13,920
Dryer	$4,964	$5,428	$7,367	$16,498	$5,671
Tensioning equipment	$33,589[b,c]	$14,439[b,d]	$14,734[b,d]	$9,796[b]	$18,560[c]
Total	$51,880	$33,981	$63,146	$33,512	$38,151

[a]All-in-one machine.
[b]Pants topper.
[c]Form finisher.
[d]Press.
Note. Costs reflect 2014 dollars.

requirements that will reduce perc emissions at other dry cleaning facilities.

Some states, including Massachusetts, will ban perc dry cleaning operations in facilities in 2020 that are also colocated in a building with additional susceptible populations, such as licensed day care centers and healthcare facilities, among others (Massachusetts Department of Environmental Protection, n.d.). California has issued more stringent regulations that will ban the use of perc in dry cleaning in 2023 (California Environmental Protection Agency, 2007). While drop-in replacement solvents for perc are available, such as n-propyl bromide or other alternatives requiring new equipment such as petroleum hydrocarbons, evidence reveals a broad range of additional health and safety concerns associated with these substitutes (Toxics Use Reduction Institute [TURI], 2012).

One alternative process that has eliminated the use of toxic solvents is professional wet cleaning. Professional wet cleaning is a water-based process to clean delicate textiles (wool, silk, rayon, natural and man-made fibers) that uses computer-controlled washers and dryers along with biodegradable detergents and specialized finishing equipment to prevent fabric shrinkage and damage (American Association of Textile Chemists and Colorists, 2007). While this alternative is not new, the technology has evolved in the past 5–10 years, resulting in significantly improved performance (TURI, 2012).

To facilitate the growth of the professional wet cleaning industry in Massachusetts, the Massachusetts Toxics Use Reduction Institute (TURI) established a dedicated Professional Wet Cleaning Grant program in 2008. The program incentivized the transition of dry cleaners to professional wet cleaning by providing technical assistance and equipment purchase offsets. During 2008–2014, grants totaling $140,000 were awarded to nine cleaners and TURI collected financial, performance, operational resource, and natural resource use data from a comparable set of five grantees—first while still using perc, and then after the transition to wet cleaning. This evaluation assessed the financial and technical feasibility of professional wet cleaning based on the Massachusetts experience of transitioning these five cleaners. Challenges confronting a broader shift in the industry towards the use of wet cleaning were also reviewed.

Methods

Each of the five shops was a small business enterprise having fewer than 10 full-time equivalent employees. The five shops allowed TURI to disclose their names: AB, Ace, KMK, King & Queen, and Silver Hangers.

TURI required each of the five cleaners to collect data for one year when the shop still operated using perc and one year when the shop operated as a dedicated professional wet cleaner. A "dedicated professional wet cleaner" was defined as having only wet cleaning equipment (washer, dryer, tensioning equipment) in the shop, and sending only incidental items (fewer than approximately one to five items per month that a shop was not comfortable cleaning in water at that time) elsewhere for processing using another method.

Standardized data collection sheets were used based on similar published evaluations (Sinsheimer, Grout, Namkoong, & Gottlieb, 2007). These published evaluations tracked similar dry cleaning facility demographics, performance measures, natural resource use, and financial expenditures impacted by the change in cleaning technology, which were incorporated into data collection instruments used in this analysis. Cost measures used in the financial assessment included

- capital investment costs associated with new wet cleaning equipment and costs associated with both perc cleaning and wet cleaning;
- cleaning performance;
- labor (both labor productivity and cleaning efficiency);
- cleaning operation costs including supplies (e.g., detergents, spotting agents, and in the case of perc, solvents), machine maintenance, as well as regulatory costs; and
- resource usage (e.g., energy, water, and sewer costs).

Each of the above measures was collected on a monthly basis and averaged. Labor hours were converted into costs using the U.S. Bureau of Labor Statistics (U.S. BLS) wage data for laundry and dry cleaning workers (U.S. BLS, 2014).

Shops completed the data sheet using cost information from similar standardized sources, including supply and equipment invoices, utility bills, and disposal invoices, among others. All shops did not track performance data, however, so the information collected for those metrics was based on averages recalled by the cleaners. Instructional letters were provided with the data collection sheets on how to collect the data, and any units of measurement (e.g., 100 ft^3 versus gallons of water) that were inconsistent between cleaners were converted whenever possible to ensure consistency among shops. At the shops where there was some language barrier, TURI staff provided assistance in guiding the cleaners through the data collection sheets and helped pull data from utility bills.

An initial cost analysis was performed to compare the cost of the investment in

TABLE 2

Performance/Quality (Average Number of Items or Money if Noted per Month)

	Silver Hanger		Ace		King & Queen		AB		KMK	
	Perc	Wet	Perc	Wet	Perc	Wet	Perc	Wet	Perc	Wet
Send-outs	5	5	0	25	0	0	3	0	0	0.58
Redos	0	3	4	4	1	0	0	0	4,033[a]	62
Claims	$1,348	$0	0	0	0.5	0	0	0	2	0.67

[a]KMK cleaners interpreted a redo as any garment that was not cleaned to their satisfaction just out of the washer that had to be spotted and sent back through. Only internal comparisons (i.e., KMK's perc versus wet cleaning experience) are appropriate.

Perc = perchloroethylene.

Note. Costs reflect 2014 dollars.

TABLE 3

Natural Resources Usage (Change in Cost and Amount Per Month From Perchloroethylene to Wet)

	Silver Hanger	Ace	King & Queen	AB	KMK
Electricity ($)	-$108	-$43	$20	-$252	-$591
Electricity (kWh)	-20%	-15%	0%	-29%	-38%
Natural gas ($)	-$305	$119	-$160	-$119	$110
Natural gas (therms)	-14%	0%	-5%	21%	-1%
Water ($)	-$1	$5	$1	-$58	-$602
Water (gallons)	-3%	25%	15%	-52%	-53%
Total natural resource cost	-$414	$81	-$86	-$429	-$1,083

Note. Costs reflect 2014 dollars.

equipment among shops, which occurred in different years. As a result, investment costs in capital equipment were all adjusted to 2014 dollars. Similarly, to compare the costs and benefits of the dry cleaning transition among the shops, data were adjusted to 2014 dollars and then modified to better reflect the potential price increase in the resources required to operate in future years (U.S. BLS, 2015). A 2% annual increase was selected as the average increase in resource prices. Wages were retrieved from the May 2014 U.S. BLS Occupational Employee Survey for Laundry and Dry-Cleaning Workers. Those wages were also increased to reflect benefits provided by employers.

Commonly used financial measures were also calculated to establish the overall value of the investment. Measures included were the payback period (the time it takes for a project to pay for itself), return on investment (ROI; financial gains recovered for every dollar invested), internal rate of return (IRR; the interest rate where the investment costs equal the benefits), and net present value (NPV; the relative value of today's investment to business over the selected time period). Each was calculated using standard equations over the average life of the wet cleaning equipment (15 years) using a discount rate of 5% to account for the time-value of the dollar (Carande-Kulis, Biddle, & Sotnikov, 2009).

Results

As shown in Table 1, the five shops included in this analysis transitioned to wet cleaning during 2008–2012 and varied in size from 1,300–2,300 square feet. The number of full-time equivalent employees ranged from three to seven, and did not necessarily correlate to the physical size of the facility.

Capital Costs

Capital costs (Table 1) included washer and dryer equipment as well as tensioning equipment, which is equipment used during the finishing process to prevent shrinkage. A form finisher and a pants topper are the tensioning equipment considered essential to wet cleaning, and are used to reshape garments during drying. Capital investments varied from $33,981–$63,145 (adjusted to 2014 dollars). This range can be attributed to variations in equipment needed by specific facilities, as well as the sophistication of the equipment purchased. The facility with the highest capital costs, King & Queen, purchased an all-in-one machine that performs both the washing and drying. Facilities (i.e., Silver Hangers) that desired higher-end finishing equipment invested more capital in that part of the process.

Performance and Quality

Each shop estimated their number of send-outs, redos, and claims at their facility as a perc user and as a wet cleaner as a measure of performance and quality (Table 2). Send-outs reflect the frequency of items sent to another shop for processing per month. Of the five cleaners, three experienced similar send-out frequencies for both perc and wet cleaning (Silver Hanger, King & Queen, and KMK). AB decreased their send-outs from three to zero. Ace experienced a significant increase in send-outs the first year. This frequency, however, was reduced in subsequent years as familiarity with the wet cleaning process increased. Redos are defined as the number of items that are not satisfactorily cleaned in the complete cleaning process and must be recleaned. Two cleaners reported similar redo frequencies (Ace and AB). Two cleaners reported a decrease in redos associated with wet cleaning compared with use of perc (King & Queen and KMK). Silver Hanger increased their redos from zero to three per month.

TABLE **4**

Operations (Labor and Productivity)

	Silver Hanger		Ace		King & Queen		AB		KMK	
	Perc	Wet	Perc	Wet	Perc	Wet	Perc	Wet	Perc	Wet
Load size (lbs)	30	50	50	50	45	50	45	20	50 lbs/hr	85 lbs/hr
Cycle time (min/load)	40	20	45	20	55	30	55	16	60	60
DEP ERP paperwork (average hrs/yr)	2	0	2	0	5	0	2	0	10	0
Spotting time (average hrs/day)	0.5	0.5	0.75	0.33	2	0.75	2	0.5	4	1
Finishing time (average hrs/day)	8	8	6	5	7	7	6	7	3.5	0.75
Training time (hrs/employee)	5	5	6	2	—	—	2	2	1–2 wks	3–4 wks
Annual labor costs	$34,557	$34,531	$27,474	$21,639	$36,559	$31,425	$32,491	$30,438	$31,322	$8,915

DEP = Department of Environmental Protection; ERP = Environmental Results Program; Perc = perchloroethylene.
Note. Costs reflect 2014 wages.

TABLE **5**

Changes in Operational Costs per Month (From Perchloroethylene to Wet)

	Silver Hanger	Ace	King & Queen	AB	KMK
Maintenance	$0	-$117	-$93	-$47	-$206
Filters	-$32	$0	$0	-$66	-$34
Solvent	-$168	-$99	-$166	-$113	-$621
Detergent	$823	$117	$225	$0	$1,048
Spotting agents	$46	-$18	$16	-$74	-$67
HW disposal	-$214	-$41	-$40	-$95	-$681
Regulatory fees	-$23	-$23	-$22	-$30	-$124
Total	$432	-$181	-$80	-$425	-$683

HW = hazardous waste.
Note. Costs reflect 2014 dollars.

Claims are the number of items that the customer is not satisfied with and submits and receives reimbursement from the cleaner. Silver Hanger reported their claims in dollars, which dropped from over $1,350 per month to zero. The remaining facilities essentially remained consistent at or close to zero claims without providing changes in dollars.

Natural Resource Use

The natural resources vital to the garment cleaning industry include electricity, natural gas (as a fuel for the boiler), and water (Table 3). Utility rates can change over time, though, so the best comparison is between usage amounts; however, both the changes in usage and costs (adjusted to 2014 dollars) are shown in the overall financial analysis (Table 3). Cleaners demonstrated a decrease in electricity use of 15%–38%, except for King & Queen where there was no change in electricity use. King & Queen was the only cleaner that invested in an all-in-one machine, which is more energy intensive than a separate washer and dryer. Natural gas use remained steady, or decreased 1%–14% at four of the five facilities. The fifth facility, AB demonstrated an increase of 21% in their use of natural gas.

Water usage at three of the facilities decreased 3%–53% and rose 15%–25% at the other two facilities. It is known that not every facility will experience water use decline if they switch to professional wet cleaning. Each of the five facilities in this study did eliminate the use of a water-cooled solvent distiller, which should have reduced their overall water usage. It is unclear why water use increased at Ace and King & Queen, though it might be explained by less efficient washers than those at the other three facilities.

Operational Costs

Labor costs associated with regulatory reporting, cleaning tasks, and training are outlined in Table 4. In Massachusetts, each facility using perc was required to report to the Massachusetts Department of Environmental Protection under the Environmental Results Program. Compliance required labor time ranging between 2–10 hours (range reflects the size of the facility), which was eliminated after becoming a wet cleaner. Spotting time—the time spent cleaning specific stains with specialized treatment agents—was greatly reduced at all but one shop, where there was no difference. Finishing time remained fairly consistent with the exception of one facility (KMK) where there was a substantial time savings when moving to wet cleaning. Training time decreased at Ace

TABLE 6

Financial Assessment

	Silver Hanger	Ace	King & Queen	AB	KMK	Average
Payback period (yrs)	3.2	4.7	8.2	2.7	0.9	2.5
NPV	$136,016	$48,715	$20,612	$111,073	$474,303	$158,142
IRR	32%	21%	9%	38%	116%	41%
ROI/ROI discounted	4.3/2.6	2.6/1.4	1.0/0.3	5.3/3.3	18.8/12.4	5.7/3.6

NPV = net present value over 15 years; IRR = internal rate of return; ROI = return on investment.
Note. Costs reflect 2014 dollars; Discount rate = 5%.

and remained the same at AB, the only two cleaners that submitted this information.

Additional operational costs at the facilities included maintenance, filters, solvent, detergent, spotting agents, hazardous waste disposal, and regulatory fees (Table 5). By switching from perc to wet cleaning, the costs for filters, solvent, hazardous waste disposal, and regulatory fees were eliminated for each facility. Maintenance costs remained at zero or were reduced when using wet cleaning equipment. The costs for detergents increased at each facility. Though some detergent is used in the solvent machines, more is used in a wet cleaning system. Spotting agent costs decreased for three of the facilities. Increases for two facilities can be attributed to the start-up costs of purchasing a new inventory of water-based spotting agents appropriate for the wet cleaning process.

Financial Assessment

Across the five cleaners, the payback period for the initial wet cleaning equipment investment averaged 2.5 years and ranged from less than 1 year up to about 8 years (Table 6). Looking forward 15 years, considering the average life span of wet-cleaning equipment, the NPV of the costs and benefits associated with an investment in wet cleaning technology averaged $158,142 (range of $20,612–$474,303)—all positive values indicating sound financial investments. Considering the 15-year wet cleaning equipment life span, there was an average ROI of $3.60 for every $1.00 invested considering a discount rate of 5%. The highest ROI saw KMK Cleaners receiving $12.40 for each $1.00 invested, while the lowest ROI still provided 33 cents for each $1.00. The lower value experienced by King & Queen was driven by their high initial investment costs (far higher than the other four cleaners). The IRR calculations demonstrate that on average, an investment in wet cleaning would be considered a good business decision if the cost of capital is less than 41%. The IRR, considering 15 years, ranged 9%–116% among the five cleaners.

Discussion

The results of this analysis demonstrate that there is a strong financial case for operating a dedicated wet cleaning shop on a scale of these five shops in the northeast. These results demonstrate the potential for large savings in operating costs, resource use, labor, and productivity. The financial assessment reveals a strong ROI, NPV, and IRR when cleaners kept their upfront capital expenditures below $50,000.

In this analysis, only one cleaner, King & Queen, did not demonstrate a strong financial return. This lack of financial return was due primarily to their decision to purchase an all-in-one machine, which is far more expensive than a separate washer and dryer. In addition to the financial benefits, the majority of wet cleaners in this analysis demonstrated similar or better performance with wet cleaning compared with using perc. These findings are consistent with other financial and technical analyses of wet cleaning transitions in California (Biddle, 2013; Sinsheimer et al., 2007). Facilities progressively tracked the majority of data used in this analysis, and used archived invoices for supplies and energy bills. Thus, the findings in this analysis are unlikely to be explained by recall bias.

Beyond the technical and financial benefits, wet cleaning technology allows business owners to create a safer and healthier work environment for themselves, their staff, and their communities. Adoption of wet cleaning corresponds to the highest form of protection and disease prevention based on the well-accepted hierarchy of industrial hygiene controls (Occupational Safety and Health Administration, 2016). This toxics use reduction intervention is a form of primary prevention—minimizing the use of and therefore exposure to toxics through process redesign and substitution of safer alternatives.

As described in the introduction, perc exposure is associated with several disease outcomes, including cancer (Guyton et al., 2014; WHO, 2014), and use in dry cleaning is the source of significant environmental contamination throughout the U.S. (Schmidt et al., 2001). Substitution of perc with wet cleaning among facilities in this analysis eliminated the use of perc and the generation of associated hazardous waste from operations. While this analysis focused on the financial and technical feasibility of transitioning from perc to wet cleaning, the value to human health and the environment by eliminating the solvent and the resulting waste needs to be underscored.

There was some variability in the data collected from the five cleaners. As with any service sector, this evaluation observed variability in quality of service based on human-controlled components. This variability is not unique to wet cleaning, however, as methods and practices of cleaners vary from shop to shop no matter what cleaning medium is being used. This variability also leads to inconsistencies in labor time and productivity.

The most efficient and effective system, based on cleaning performance and financial rewards, would incorporate effective equipment, adequate training, and efficient workflow. This combination is a feasible scenario to achieve, as demonstrated by one cleaner in this assessment, KMK, which achieved the greatest natural savings, the greatest labor productivity, and the highest ROI.

There still exists variability in the data based on data collection methods used by each cleaner. For example, KMK considered a redo differently than the other cleaners, therefore making that data set difficult to compare with other cleaners. This performance/quality metric was not monetized, however, so it had no effect on the overall

financial assessment. Also, Silver Hanger reported their costs rather than item numbers for claims, also making this data set difficult to compare with other cleaners.

Conclusion

This analysis affirms the business case for wet cleaning, adding to the body of existing evidence that professional wet cleaning is technically and financially feasible, and environmentally preferable. When the TURI Wet Cleaning program began in 2008, there were no dedicated wet cleaners operating in the state to our knowledge. Today, Massachusetts has more than a dozen dedicated wet cleaners in operation.

Garment cleaners considering a switch to professional wet cleaning can use the information and data presented here and elsewhere (Sinsheimer et al., 2007) to make informed decisions about equipment purchasing and staff training to maximize their ROI. Each of the cleaners included in this study, as well as others across the state, are resources for those evaluating their options when moving away from perc. As more cleaners move toward professional wet cleaning, both in Massachusetts and in other states, the garment cleaning sector and the communities they support will reap the benefits.

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References

American Association of Textile Chemists and Colorists. (2007). *AATCC 2007 technical manual—A glossary of AATCC standard terminology*. Research Triangle Park, NC: Author.

Biddle, E. (2013). Business cases: Supporting PTD solutions. *Professional Safety, 58*(3), 56–64.

Blair, A., Stewart, P.A., Tolbert, P.E., Grauman, D., Moran, F.X., Vaught, J., & Rayner, J. (1990). Cancer and other causes of death among a cohort of dry cleaners. *British Journal of Industrial Medicine, 47*(3), 162–168.

California Environmental Protection Agency Air Resources Board. (2007). *Final statement of reasons for rulemaking including summary of comments and agency responses: Public hearing to consider adoption of the amendments to the control measure for perchloroethylene dry cleaning operations and adoption of requirements for manufacturers and distributors of perchloroethylene*. Sacramento, CA: Author. Retrieved from http://www.arb.ca.gov/regact/2007/perc07/fsor.pdf

Carande-Kulis, V., Biddle, E., & Sotnikov, S. (2009). *Investing in health and safety: A business case resource guide*. Atlanta, GA: Centers for Disease Control and Prevention. Retrieved from http://www.cdc.gov/niosh/nioshtic-2/20038320.html

Doherty, R.E. (2000). A history of the production and use of carbon tetrachloride, tetrachloroethylene, trichloroethylene and 1,1,1-trichloroethane in the United States: Part 1—Historical background; carbon tetrachloride and tetrachloroethylene. *Environmental Forensics, 1*(2), 69–81.

Guyton, K.Z., Hogan, K.A., Scott, C.S., Cooper, G.S., Bale, A.S., Kopylev, L., . . . Chiu, W.A. (2014). Human health effects of tetrachloroethylene: Key findings and scientific issues. *Environmental Health Perspectives, 122*(4), 325–334.

Ma, J., Lessner, L., Schreiber, J., & Carpenter, D.O. (2009). Association between residential proximity to PERC dry cleaning establishments and kidney cancer in New York City. *Journal of Environmental and Public Health, 2009*, 1–7.

Massachusetts Department of Environmental Protection Industry Performance Standards, 310 CMR § 7.26 (n.d.). Retrieved from http://www.mass.gov/eea/docs/dep/service/regulations/310cmr07.pdf

Occupational Safety and Health Administration. (2016). *Transitioning to safer chemicals: A toolkit for employers and workers*. Retrieved from https://www.osha.gov/dsg/safer_chemicals/why_transition.html

Schmidt, R., DeZeeuw, R., Henning, L., & Trippler, D. (2001). *State programs to clean up dry cleaners*. Washington, DC: U.S. Environmental Protection Agency States Coalition for the Remediation of Dry Cleaners. Retrieved from https://drycleancoalition.org/survey

Schreiber, J.S., Hudnell, H.K., Geller, A.M., House, D.E., Aldous, K.M., Force, M.S., . . . Parker, J.C. (2002). Apartment residents' and day care workers' exposures to tetrachloroethylene and deficits in visual contrast sensitivity. *Environmental Health Perspectives, 110*(7), 655–664.

Sinsheimer, P., Grout, C., Namkoong, A., & Gottlieb, R. (2007). The viability of professional wet cleaning as a pollution prevention alternative to perchloroethylene dry cleaning. *Journal of the Air & Waste Management Association, 57*(2), 172–178.

Toxics Use Reduction Institute. (2012). *Assessment of alternatives to perchloroethylene for the dry cleaning industry* (Methods and Policy Report No. 27). Retrieved from http://www.turi.org/TURI_Publications/TURI_Methods_Policy_Reports/Assessment_of_Alternatives_to_Perchloroethylene_for_the_Dry_Cleaning_Industry._2012

U.S. Bureau of Labor Statistics. (2014). *Occupational employment and wages, May 2013* (Report No. 51-6011 Laundry and Dry-Cleaning Workers). Retrieved from http://www.bls.gov/oes/2013/may/oes516011.htm

U.S. Bureau of Labor Statistics. (2015). *CPI inflation calculator*. Retrieved from http://www.bls.gov/data/inflation_calculator.htm

U.S. Environmental Protection Agency. (2016a). *Dry cleaning emission standards: Basic information*. Retrieved from http://www.epa.gov/drycleaningrule/basic.html

U.S. Environmental Protection Agency. (2016b). *Integrated risk information system assessments: Tetrachloroethylene* (CASRN No. 127-18-4). Retrieved from https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=106

References

U.S. Environmental Protection Agency National Perchloroethylene Air Emission Standards for Dry Cleaning Facilities, Final Rule 2006. 40 CFR § 63 (2006). Retrieved from https://www.federalregister.gov/documents/2006/07/27/06-6447/national-perchloroethylene-air-emission-standards-for-dry-cleaning-facilities

World Health Organization, International Agency for Research on Cancer. (2014). Trichloroethylene, tetrachloroethylene, and some other chlorinated agents [Monograph]. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, *106*. Lyon, France: Author. Retrieved from http://monographs.iarc.fr/ENG/Monographs/vol106/mono106-002.pdf