A Comparative Analysis of Perc Dry Cleaning and an Alternative Wet Cleaning Process

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Table of Contents

Introduction

Findings

Conclusion

Recommendations

Epilogue

Appendices

References

List of Figures

List of Tables

PROLOGUE

In March 1994, the authors of this report, five graduate students at the University of Michigan, formed a team whose purpose was to examine an alternative to perchloroethylene-based (perc) dry cleaning. At that time, a chlorine-free wet cleaning alternative was receiving increased attention from various organizations. Based upon initial reports of cost and performance data, it appeared that wet cleaning was a viable alternative to perc dry cleaning.

With the guidance of the project's faculty advisor, we, the student team, began a comparative analysis of wet cleaning and perc dry cleaning. This study was not funded by any outside sources. Rather, the work was performed to meet the requirements of a master's thesis. In conducting our research and preparing this report, we sought the views and opinions of several organizations and individuals who have a stake in this issue. We drew upon the expertise of dry cleaners, wet cleaners, perc manufacturers, regulators, dry and wet cleaning machine manufacturers, trade associations, and environmental groups. Each of these stakeholders had the opportunity to review a draft of this report, and many responded. The feedback we received from reviewers included both points of fact and points of view which some felt we had not thoroughly addressed. This feedback was valuable, and we have attempted to incorporate these data and perspectives into the final report.

This report contains technical data and research findings comparing the two garment cleaning systems across five criteria. This report does not provide an account of the specific political actions being taken by some stakeholders. It is important to note that the increased focus on wet cleaning has become highly politicized, and a significant level of distrust exists among various stakeholders. This distrust pertains to different opinions about the effectiveness of wet cleaning, its ability to clean all garments, and its economic viability. In a wet cleaning demonstration project jointly conducted by several stakeholders, many participants disagreed with the published findings. They felt that the conclusions drawn from the project were premature and over-representative of the positive attributes of wet cleaning.

We received feedback from some stakeholders that the draft report we circulated for comments contained a bias toward wet cleaning. In response, we have asked for elaboration, and whenever possible we have tried to balance the information by including more than one perspective. We have relied on existing published data, site visits, and interviews with those having expertise in this area as our basis for research. It has been suggested that we establish and operate a wet cleaning demonstration project in order to obtain data and present a clear, unbiased analysis, rather than rely on existing data. We had neither the resources to do so nor the technical expertise. We feel we have presented a comprehensive analysis using the available information.

It is important to understand that this study is an analysis comparing two garment cleaning systems with *each other*. Thus, we made no attempt to include a comprehensive risk assessment of perchloroethylene dry cleaning. We view the analysis as a step towards determining the opportunity for source reduction, rather than focusing on management of pollution after its creation. Our intention is that this document will serve as a resource to highlight the key issues of this debate and as a reference for policy makers, dry cleaners, associations, environmental groups, equipment manufacturers, perc manufacturers, and other interested parties.

DEFINITIONS*

For cleaning processes and technologies discussed in this report.

1. A **closed-loop, dry-to-dry machine** is a dry cleaning machine in which cleaning, extraction, and drying are all performed in the same unit and which recirculates perc-laden vapor through a refrigerated condenser or other control system, with no exhaust released to the atmosphere during the drying cycle.

2. A **carbon adsorber** is a pollution control device that traps perc vapors from the dry cleaning machine's exhaust using activated carbon.

3. **Dry cleaning,** as used in this study, refers to professional clothes cleaning using the chemical solvent perchloroethylene.

4. **Fine washables** include garments made of fabrics such as linen, silk, rayon, cotton-knit, and woolens; garments with special trims, beads, etc.; and clothes with pleats and intricate tailoring which requires special pressing and finishing.

5. **Laundering** is the manual or machine washing of textiles, often men's shirts, using water and cleaning detergents. For purposes of this study, laundering is not considered part of the dry and wet cleaning processes used to clean fine washables.

6. **Multiprocess wet cleaning** is a water-based cleaning process in which garments are examined and treated individually. Depending on the fabric type of the garment and the degree of cleaning required, multiprocess wet cleaning can involve a number of cleaning techniques, including steaming and spotting, gentle hand washing, tumble drying, and scrubbing.

7. **Perchloroethylene** or **"perc"** is the chemical solvent used by over 80 percent of dry cleaners in the United States. Perc is designated as a hazardous air pollutant under Section 112 of the Clean Air Act. Also known as PCE or tetrachloroethylene.

8. A **refrigerated condenser** is a vapor recovery system. Perc vapors are circulated through the refrigerated condenser and chilled back into liquid form for reuse.

9. A **separator** is any device used to recover perc from a water-perc mixture.

10. **Spotting** is the manual process of removing stains and soiling with specific stain removing agents before or after dry cleaning, wet cleaning, or laundering.

11. A **still** is a device used to volatize and recover pure perc from used solvent.

12. A **transfer machine** is an older perc-based dry cleaning machine in which cleaning and extraction are performed in one unit, and drying is performed in a separate unit.

13. **Wet cleaning** is a process of clothes cleaning based on the use of water and detergents. Wet cleaning does not use the solvent perchloroethylene. For purposes of this study, wet cleaning is a combination of advanced water-based cleaning machines (70%) and multiprocess wet cleaning (30%).

14. **Wet machines** are specially designed machines which can be used to clean fine washables. Wet machines can be programmed for desired cleaning time, mechanical action, temperature, and extent of water extraction.

*Definitions number 1, 2, 3, 6, 7, 8, and 9 were modified from definitions found in Title 17 of the California Code of Regulations, Section 93109 "Final Regulation Order: Air Toxic Control Measure for Emissions of Perchloroethylene from Dry Cleaning Operations." See subsection (a), "Definitions." Definitions of laundering and spotting have been modified from definitions found in EPA's report, "Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and an Alternative Process," page 1–8.

EXECUTIVE SUMMARY

Most people don't think about *how* their clothes are going to be cleaned when they drop them off at a neighborhood dry cleaner. They are only interested in receiving professionally cleaned and pressed clothing, at a reasonable price, within a short amount of time. But the cleaning method a professional cleaner chooses affects the environment, human health, the profitability of the business, the number of regulations with which the business must comply, and the cleanliness and appearance of the clothes.

As concern has increased over the manufacture, use, and disposal of halogenated solvents and chlorinated chemicals, the search for alternatives and pollution prevention strategies has become more urgent. Perchloroethylene (PCE, or "perc") is the chlorinated solvent used by the majority of dry cleaners today. In an effort to reduce perc use, people in the garment care industry and environmental community have been experimenting with, analyzing, debating, and lobbying over an alternative wet cleaning method that would replace the need for perc.

This study is a comparative analysis of two professional clothes cleaning methods: (1) traditional perc dry cleaning and (2) wet cleaning, which uses water and biodegradable detergents in sophisticated washing machines (70 percent) in conjunction with a hand-washing method called multiprocess wet cleaning (30 percent). This study is not a risk assessment of perc. It is a comparison of two cleaning methods, one which relies on a toxic solvent and one which does not. The study uses evaluative techniques from Life Cycle Assessment and Life Cycle Design. It analyzes the use and disposal of cleaning agents, but does not cover the manufacturing and resource extraction impacts of these cleaning agents; therefore, it understates the full environmental impacts, risks, and associated regulatory issues of perc and wet cleaning. The two cleaning methods are analyzed with respect to environmental and human health impacts, cleaning performance, economics, and regulations. The study does not score either cleaning method, but instead provides a framework so that policymakers, regulators, dry cleaners and consumers can assess the relative benefits and disadvantages of both cleaning methods.

FINDINGS

ENVIRONMENTAL IMPACTS

Perc is a member of the chlorinated solvents family. There is increasing concern about the use of chlorinated compounds due to their persistence in the environment and their potential to bioaccumulate. There are no known, naturally occurring sources of perc in the environment.

Perc is used by more than 80 percent of U.S. dry cleaners. In 1991, perc consumed by the commercial dry cleaning sector, which consists of about 30,000 machines in operation nationwide, totaled 122,700 metric tons (270 million pounds).

Of this amount, about two-thirds, or 180 million pounds, is released annually into the atmosphere. Some of perc's breakdown components, such as vinyl chloride and phosgene, are toxic to humans; another, trichloroacetic acid, is a known herbicide that causes forest damage.

Most of the remaining 90 million pounds are captured in the form of a solid waste, which is classified as hazardous under the Resource Conservation and Recovery Act. Disposal of waste products containing perc must be handled by authorized facilities. Most cleaners pay to have perc-laden waste removed by an off-site disposal service, which reclaims some of the waste and sells the rest to cement kiln incinerators. Perc is also discharged into sewer systems each year in the form of wastewater. Perc can migrate through concrete sewer pipes and also escape through sewer systems which are designed to leak. Once in the soil, perc is mobile and can reach groundwater, where it remains fairly stable. Perc contamination of groundwater has been documented in many areas of the country. For instance, in California's Central Valley region, more than a third of 750 tested wells contained perc, many at levels higher than the permissible limit. Dry cleaning was found to be the likely source of contamination in 20 out of 21 wells that were extensively tested.

A dry cleaning machine using the latest perc technology consumes more electricity to clean a garment than a high-tech wet cleaning machine; this higher demand for energy generation causes more air pollution over time. This is primarily because the dry cleaning machine employs energy-intensive emission control technology equipment, such as refrigerated condensers.

The wet cleaning machine consumes a great deal of water since that, rather than a chemical solvent, is the cleaning medium. Thus, the environmental impacts of using and treating water are much higher with wet cleaning than with dry cleaning. Further study is being done on recycling water, which can reduce wet cleaning's negative environmental impacts.

HUMAN HEALTH IMPACTS

The National Institute for Occupational Safety and Health (NIOSH) recommends perc be handled as a human carcinogen. The State of California has designated perc as a carcinogen. The International Agency for Research on Cancer plans to revise its classification of perc from "possible" carcinogen to "probable" carcinogen. Currently, the U.S. EPA's unofficial classification of perc falls on a continuum between possible (classification C) and probable (classification B2) human carcinogen. In 1991 the EPA's Science Advisory Board noted that, due to existing levels of uncertainty and the widespread use of perc, it would be wise to reduce workers' exposure.

A 1994 NIOSH study found significant excesses of esophageal cancer and elevated "observed to expected" numbers of deaths from intestinal and pancreatic cancer in populations exposed to perc. A 1993 Boston University study associated perc-contaminated drinking water supplies with an "elevated relative risk" of leukemia and "increased relative risk" of bladder cancer. Previous studies of human populations dealt with people exposed to a variety of solvents used in the dry cleaning industry and thus were unable to isolate the contribution from perc; the NIOSH and Boston University studies are significant because they did isolate perc's effects.

As recently as 1989, the Occupational Safety and Health Administration (OSHA) lowered the Permissible Exposure Limits (PELs) for workers' exposure to perc from 100 parts per million (ppm) to 25 ppm. However, due to a procedural technicality, an industry-sponsored lawsuit overturned the new standard. Although dry cleaners are advised to limit exposure to 25 ppm, workers can still legally be exposed to levels OSHA has ruled unsafe.

Some perc can remain in garments after dry cleaning, resulting in human exposure. According to one study, after 100 days only 40 percent of the perc, which was held in the fiber pores, had diffused to the surface and evaporated.

The adverse health impacts associated with dry cleaning result from exposure to perc and the spotting agents. Wet cleaning, which uses nontoxic detergents, essentially eliminates the known health risks to cleaners and the public associated with perc use.

PERFORMANCE

Perc is an effective clothes cleaning solvent. It dissolves lipophilic stains such as oils, greases, fats, and waxes; does not readily penetrate textile fibers; and evaporates quickly, reducing the potential for garment shrinkage. Perc is non-flammable and easily treated for reuse.

Water can clean many garments, but it is not capable of dissolving lipophilic soils. With wet cleaning, nonchlorinated solvents are used to treat these stains. For the large majority of fabrics, water does not dissolve or weaken fibers or cause bleeding of dyes, and water is compatible with readily available detergents.

Because garment shrinkage results, in part, from over-drying, a wet cleaner must pay special attention to the residual moisture content in a garment while drying. Wet cleaners eliminate shrinkage problems by using specially designed drying machines, which are programmed for specific garments' needs, or by drip-drying.

Environment Canada's Green Clean wet cleaning demonstration project received 177 survey responses during June, July and, August 1994, with 97 percent indicating the clothes were clean overall and 98 percent responding that they would have their clothes wet cleaned again.

ECONOMICS

Our model facility analysis found that wet cleaning can be an economically viable alternative to dry cleaning. The profitability of wet cleaning depends on many variables, including the cost of labor, equipment, detergents, electricity, and water. Wet cleaning facilities in operation today offer prices similar to those offered by dry cleaners.

Uncertainties exist regarding the amount of labor required for wet cleaning. Labor is one of a professional cleaner's biggest costs; therefore, worker productivity is one of the largest factors in analyzing the profitability of wet cleaning. To compete with dry cleaning, the wet cleaner may need to invest in worker training.

Wet cleaning involves significantly fewer up-front capital expenditures than dry cleaning. For example, the cost of an Aqua Clean System washer and dryer is roughly $30,000. In comparison, a similar-size dry cleaning machine costs roughly $54,000.

The cost of perc and the detergents used with it is significantly cheaper than the cost of wet cleaning detergents and sizing agents. However, dry cleaning entails additional costs associated with disposal of hazardous, perc-contaminated wastes. The disposal costs of perc make it more expensive than the cleaning agents used in wet cleaning.

Wet cleaning involves significantly lower electricity costs than dry cleaning, in large part because dry cleaning uses energy-intensive pollution control equipment. However, these savings are fully offset by wet cleaning's higher water-usage expenses.

REGULATIONS

Dry cleaners using perc must comply with several environmental statutes, such as the following. The Occupational Safety and Health Act limits permissible exposure levels in the workplace. The 1990 Clean Air Act Amendments (CAAA) regulate emissions to the atmosphere. The Resource Conservation and Recovery Act (RCRA) governs disposal of perc as hazardous waste. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) establishes liability for groundwater and soil pollution. There are also various state regulations.

The 1990 CAAAs require Maximum Available Control Technology to reduce atmospheric emissions. However, the National Emission Standards for Hazardous Air Pollutants, promulgated by the U.S. EPA to meet the CAAA, allow certain cleaners to retrofit and maintain older technology such as vented or transfer machines. Therefore, not all cleaners are using the most effective technology to limit emissions (the closed-loop dry-to-dry machines).

The 1984 RCRA Amendments stipulate disposal methods for perc-contaminated waste; compliance costs for a dry cleaner average several thousand dollars per year.

Historically, dry cleaners have legally poured perc-laden wastewater into the sewer. Under CERCLA, dry cleaners are liable for these past disposal practices if they result in contaminated groundwater or soil. Certain state dry cleaning associations are establishing funds to pay for such liability-related claims.

Enforcement of dry cleaning regulations is based on self-reporting, inventory, and record keeping. Due to the fragmented nature of the industry, the small number of regulatory inspectors, and the abundance of facilities, not all dry cleaners are inspected. Wet cleaners are not affected by the above-mentioned regulations because their detergents are nontoxic and biodegradable; a potential regulatory concern for them is their higher volumes of wastewater. Because dry cleaning uses perc, costly regulations are needed to reduce environmental burden and protect human health. Wet cleaning is a pollution-prevention approach to protecting the environment without costly regulations.

RECOMMENDATIONS

Our study emphasized the importance of five criteria: environment, human health, economics, performance, and regulations. The dry cleaning industry has expressed concern about the economic and performance criteria: if wet cleaning cannot meet the base level of performance established by dry cleaning, it will not be acceptable to customers; if it is not economical for small commercial dry cleaners, it will not be adopted voluntarily. These comparisons are difficult to conduct at this point, since wet cleaning technology and practices are still evolving. Most wet cleaners have been operating for less than one year, and they are being compared to an industry with more than 40 years of experience. Until wet cleaning facilities have been operating long enough to collect empirical data on both cost and performance, dry cleaners will continue to maintain a level of skepticism about the practicality of wet cleaning. The following recommendations address these concerns.

DATA COLLECTION

Additional data are needed to resolve uncertainties with wet cleaning. To ensure acceptance and accuracy of the results, tests should be performed with input from all involved stakeholders. The following research activities might resolve uncertainties.

- Examine the long-term impacts of continued wet cleaning on garments; compare these results with the long-term impacts of continued dry cleaning on garments.
- Quantify the labor requirements of wet and dry cleaning and identify how variations in volume and garment/fabric types affect wet cleaning's economic viability.
- Analyze (a) the chemicals released into wastewater when previously dry-cleaned and spotted clothes are wet cleaned and (b) the impact these chemicals could have on water quality.
- Develop a dose-response model to better predict the health effects of various levels of perc exposure.
- Research and develop wastewater recycling technologies for wet cleaning.
- Survey customers' expectations and attitudes toward professional clothes cleaning. Additional market research will help inform dry cleaners about the level of customer demand for wet cleaning.

INCENTIVES

Federal and state governments should help wet cleaners experiment with alternative technologies. Incentives such as the following would encourage cleaners to set up alternative cleaning systems, because the financial risk involved would be reduced.

- Provide subsidies, loan guarantees, low-interest loans, and tax breaks to purchase wet-cleaning equipment.
- Provide government-subsidized training programs to teach dry cleaning workers the more complex wet-cleaning techniques.
- Change the Federal Trade Commission's garment-care labeling regulation to use the term "professional cleaning" instead of "dry cleaning."

IMPLEMENTATION

Dry cleaners need to begin looking critically at their garment streams and experimenting with wet cleaning on appropriate items in order to become more familiar with wet cleaning's potential. To facilitate the on-site implementation of wet cleaning, dry cleaners could do the following.

- Attend workshops and training programs, on wet cleaning.
- Consider a wet-cleaning machine when expanding capacity. This would provide both cleaners and customers with greater flexibility in choosing how to clean garments.

- While experimenting with cleaning fine washables in the wet machine, the cleaner can immediately capitalize on the investment: the wet machine can be used to clean leathers and suedes on-site. (Cleaners who use only perc machines have to send leathers and suedes to special facilities for cleaning.)

INFORMATION DISSEMINATION

An educational campaign can inform the public and dry cleaners about wet cleaning in order to facilitate its adoption. Efforts may include the following elements.

- Provide useful information on wet cleaning to a variety of interested stakeholders. Federal and state governments should act as information clearinghouses, referring dry cleaners to technical assistance, reference guides, wet cleaning equipment manufacturers, and funding sources.
- Create a guidebook that provides practical information about wet cleaning technologies and processes to cleaners who are considering adopting wet systems. It should include contact information for wet cleaning trainers, manufacturers, sales representatives, suppliers, and stores.
- Launch a consumer education campaign about wet cleaning. This could help customers make more informed choices about how their clothes are cleaned, and develop a market for wet cleaning.
- Continue and expand workshops on wet cleaning. Organizations such as the Neighborhood Cleaners Association are already providing members with information and training on wet cleaning. Research and development should focus on improving the existing wet cleaning technology base because of its immediate benefits.

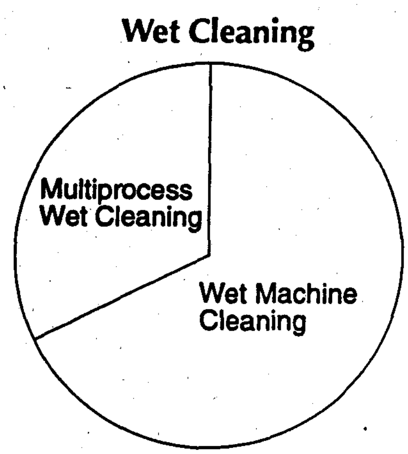
Summary of Findings of a Multicriteria Comparison of Perc Dry Cleaning and a Wet Cleaning System

Criteria	Perc Dry Cleaning	Wet Cleaning
Human Health	• Strong evidence suggests the human carcinogenicity and neurotoxicity of perc.	• Little or no toxicity is associated with inputs to the cleaning process.
Environmental	• Perc is a chlorinated compound. Over 269 million pounds of perc were used by commercial U.S. dry cleaners in 1991. • Numerous problems are documented on perc releases into air, land, and water. • Emission-control technology is energy-intensive.	• Principal inputs are water and nontoxic cleaning agents, so there are minimal adverse impacts. • The process uses significantly more water. This could be partially mitigated by recycling the water. • Machines operate on less energy.
Performance (i.e., cleanliness and appearance of garments)	• Based on the limited testing of wet cleaning, both systems show advantages and disadvantages. Specific performance results are dependent upon fiber type, garment construction, machine technology, and process. • Both cleaning systems produce results which appear satisfactory to customers.	
Economic	• Additional wet cleaning cost data is needed. • Preliminary analysis indicates that the two methods have roughly comparable costs and profits. • Estimates of the profitability of wet cleaning hinge on assumptions regarding wet cleaning's labor requirements.	
Regulatory	• Many federal, state, and local regulations govern perc use and releases to air, land, and water.	• Minimal regulatory burdens on professional cleaners exist.

INTRODUCTION

I. INTRODUCTORY INFORMATION

Approximately 80 percent of the dry cleaning industry uses the solvent perchloroethylene (also known as "perc," PCE, and tetrachloroethylene) to remove soils and odors from clothes.[1] Perc is one of 10,000–15,000 chemicals in commercial use that are manufactured using chlorine. Currently there is a debate between industry and environmentalists[2] about the production and use of chlorine chemicals. A significant fraction of these chemicals pose ecological and human health risks because of their toxicity, persistence in the environment, and potential to bioaccumulate in the food chain.[3] In this report, we are addressing the application of one of these chemicals, perc. Perc's properties indicate that it is not as persistent and bioaccumulative as other chlorinated compounds, but because of its toxicity, the widespread human exposure to perc, and its high mobility in the environment, it poses significant human and ecological health risks.



This study is a comparative analysis of two professional clothes cleaning methods: (1) traditional perc dry cleaning, and (2) a wet cleaning method, that uses water and biodegradable detergents in sophisticated washing machines in conjunction with a method called multiprocess wet cleaning. We view this analysis as a step toward determining the opportunity for source reduction, rather than focusing on management of pollution after its creation. Our intention is that this document will highlight the key issues of this debate, point out preliminary findings, and serve as a resource for policy makers, dry cleaners, associations, environmental groups, or other interested parties.

A Climate of Change

In the past two decades, Congress has passed a series of laws designed to protect the environment. The laws set contamination standards for air, soil, and water; require industries to track and control releases of harmful chemicals; and cast a wide net of liability for past and present environmental damage. Initially, the focus was on large users; over time, as large users have come into compliance, the emphasis has shifted to small businesses. The regulations and their associated compliance costs have had a significant impact on the dry cleaning industry, which is currently dominated by small, independent businesses.

In December 1991, EPA proposed National Emission Standards for Hazardous Air Pollutants (NESHAPs) to regulate, among other things the dry cleaning industry's emissions of perchloroethylene. These regulations went into effect in September 1993 and are to be fully implemented by September 23, 1996.[4] The regulations have caused dry cleaners to significantly revise operations, track their use and disposal of perc, and assess their liability for environmental and health issues resulting from perc. However, states retain the ability to pass laws stricter than these federal standards. While the federal law mandates compliance by September 23, 1996, there is no requirement that states finish imposing their regulations by that time. This creates a climate of uncertainty for dry cleaners who currently need to invest in new pollution control technologies in order to safely and legally use perc but do not know if stricter state standards will be passed in years to come.

The regulations have also increased the awareness of dry cleaners' employees, customers, neighbors, and the general public to the health and environmental risks associated with dry cleaning. In addition, building owners are increasingly concerned about the potential liability of renting to dry-cleaners. For example, one of their concerns is with the potential for groundwater contamination from wastewater disposal. Dry cleaners in many states can still legally dispose of their wastewater through the municipal sewer system. Sewer pipes, by design, release water; dry cleaning wastewater is poured down the sewers and thus may be released, causing contamination of groundwater supplies. The liability issues for dry cleaners are at the point where some accept that if they have been in business for many years, their land may have limited resale value due to contamination.

Perc has been linked with a variety of human health effects in dry cleaning workers and the general public. Two routes of exposure are through the ambient air in dry cleaners and through contaminated drinking water supplies. A 1994 National Institute for Occupational Safety and Health (NIOSH) study found significant excesses of esophageal cancer in dry cleaning workers exposed to the solvent perchloroethylene in the shop air.[5] In addition, in some parts of the country, dry cleaners are housed in residential buildings. Studies have shown that the contaminated shop air can migrate upwards and cause unsafe levels in residences. This is especially a problem in New York City where cleaners commonly share buildings with residential units. Another study, sponsored by Boston University and released in 1993, analyzed the effects of accidental exposure to perc from a contaminated drinking water supply. The water was contaminated when perc from the plastic lining of drinking water distribution pipes leached into the water supply. The study found that the population served by this water source had a higher incidence of leukemia due to the contamination.[6]

A Course of Action

Dry cleaners face a unique opportunity to respond either reactively, by keeping up with the regulations, or proactively, by exploring alternatives and rethinking options in textile cleaning to minimize waste production so that the need for "end-of-the-pipe" solutions is minimized or obviated. In fact, over the past five years, dry cleaners have reduced the amount of perc used by 40 percent and the dry cleaning associations have worked with their members to reduce emissions and to practice proper maintenance and handling.[7] On a larger scale, textile manufacturing itself could change to allow garments to be more easily cleaned using alternative methods. This report assesses the current state of the industry, evaluates the immediate issues it faces, and explores the viability of the most promising of the alternatives to conventional dry cleaning.

The Comparative Analysis

The approach taken is a comparative analysis of conventional dry cleaning and an alternative process, wet cleaning. The analysis focuses on five basic evaluation criteria: health impacts, environmental impacts, performance capability, applicable regulations, and economic costs. This assessment will help professional cleaners, policy makers, and customers critically weigh the choices available and develop a strategy for ensuring the industry's competitiveness.

For the purposes of this analysis we are differentiating between laundering, multiprocess wet cleaning, and wet machine cleaning. The average cleaner currently <u>launders</u> approximately 25 percent of the garments it cleans.[8] The bulk of these laundered garments are items such as men's dress shirts. While some cleaners call this wet cleaning, in our study, laundering is not considered as wet cleaning. In our study, wet cleaning consists of a two-part process designed as an alternative to perc for cleaning fine washables. The processes include <u>wet machine cleaning</u> and a method known as <u>multiprocess wet cleaning</u>. Wet machine cleaning is a process in which specially designed machines are programmed for desired cleaning time, mechanical action, temperature, and extent of water extraction. Multiprocess wet cleaning uses one or more of the following techniques: steaming and spotting, tumble drying, gentle hand washing, and scrubbing. This process is discussed in more detail in the section on water-based alternative cleaning systems. This comparative analysis looks at perc dry cleaning with a closed-loop, dry-to-dry machine and a wet cleaning system in which 70 percent of the fine washables are wet machine cleaned and 30 percent are multiprocess cleaned.[a]

The sections following this introduction provide 1) background on the industry and the cleaning processes under analysis; 2) a discussion of the methodology used, the scope of the study, and an inventory of the industry and the inputs and outputs of the two cleaning processes; and, 3) an assessment of the two clothes cleaning processes with respect to the five criteria: human health and environmental impacts, cleaning performance, economics, and regulatory requirements.

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[2] "As Perchloroethylene Use is Reduced, Dry Cleaning May Get Wetter," *C&EN Magazine* (June 20, 1994):14.
[3]U.S. EPA, Chapter 9: "Risk Characterization of Dioxin and Related Compounds," *Summary Report of Dioxin Reassessment* (May 2, 1994), as cited in "Dioxin Reassessed: Part 1," *Rachel's Hazardous Waste News* 390 (June 7, 1994).
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[5]Avima M. Ruder et al., "Cancer Mortality in Female and Male Dry-Cleaning Workers," *Journal of Medicine* 36, no. 8 (August 1994): 867–74.
[6]Ann Aschengrau et al., "Cancer Risk and Tetrachloroethylene-contaminated Drinking Water in Massachusetts," *Archives of Environmental Health* 8, no. 5 (September/October 1993): 284–92.
[7]Personal communication with William Seitz, Executive Director, Neighborhood Cleaners Association, (January 3, 1995); William E. Fisher, "C. Current Pollution Prevention Initiatives: An Integral Part of the Industry's CERCLA Amendment," (November 9, 1994). This paper was one of written summaries of agenda items discussed on October 24, 1994, in a meeting between dry cleaning industry associations and the U.S. EPA. This paper was an enclosure in a letter to David Doniger, Office of Air and Radiation, U.S. EPA, from Brooksher Banks, FLARE Director. Fisher is Senior Vice President of the International Fabricare Institute.
[8]Environment Canada, "Priority Substances List, Assessment Report: Tetrachloroethylene" (Ontario, Canada: Environment Canada, 1994).

[a]For more information on this percentage breakdown, see the section on Water-Based Alternative Cleaning.

II. BACKGROUND INFORMATION

Industry Profile

There are three types of dry cleaning facilities: industrial cleaners that clean uniforms for commercial and industrial customers; commercial cleaners that are the small, independently operated or franchise neighborhood cleaners; and coin-ops where individuals can perform self-service dry cleaning. This comparative analysis studies commercial cleaners, which make up approximately 90 percent of the industry. Coin-op machines are on the decline and are a small share of the market (approximately nine percent), and industrial cleaners are less than 1 percent of the industry.[1,2]

Approximately 40 years ago, a major transition in the professional cleaning industry occurred with the introduction of perc. Perc eliminated many of the problems of the previously used solvents such as petroleum solvents, which are flammable. With the use of perc, dry cleaning became a relatively safe process. In addition, dry cleaning appealed to independent small business owners who could start up the business and reap direct financial benefits proportionate to the hours they were willing to work. As a result, small commercial dry cleaners, which marketed convenience and high-quality service, opened in most neighborhoods. The large number of commercial perc machines in operation today, approximately 30,000,[3] has made the industry extremely competitive on the basis of price, turnaround time, and customer service.

Several different trade associations exist within the industry, such as the Korean Dry Cleaners Association, International Fabricare Institute, the Neighborhood Cleaners Association, and other, statewide associations. However, there is no one national umbrella association. This lack of unification in the industry can make it difficult to disseminate information. Consequently, professional cleaners often rely on their suppliers, such as The Dow Chemical Company, which manufactures perc, for information on industry-wide developments and regulatory compliance.[4]

Industry-wide analysis is also complicated by the wide variety of machines used by commercial dry cleaners. Due to the rapid changes in technology over the past decade and the 10- to 20-year life-expectancy of a dry cleaning machine, some cleaners are still operating systems that require manual transfer of clothes between the washer and dryer while others have systems which are entirely closed-loop. Add-on technologies to control emissions further increase the variety of technology in use. This range of technology also complicates industry-wide analysis because the different technologies create a wide range of impacts on employee health, the environment, performance, cost, and regulations.

Current regulatory changes have required dry cleaners to upgrade equipment and change operating practices. However, the regulations are complicated, and it is likely to be difficult for individual dry cleaners to determine the exact changes they are required to make. With small state budgets for enforcement and a lack of cohesion in the industry, some shop owners may intentionally or unintentionally continue to operate in ways that put themselves, their employees, and their neighbors at risk of environmental and health impacts.

For years, dry cleaners have used water-based cleaning methods to launder shirts and a small percentage of other clothes. However, more advanced wet cleaning technology is in its infancy stage in the United States. In the past few years, both Canada and the U.S. have run wet cleaning demonstration projects. Currently, Canada is operating a demonstration project evaluating the use of several wet machine technologies. The U.S. Environmental Protection Agency has already completed a demonstration project evaluating multiprocess wet cleaning, and is designing pilot wet machine projects in Chicago, Los Angeles, and Indianapolis. Although customer reactions to the EPA multiprocess demonstration project were favorable, the industry criticized the findings. The demonstration project operated in November and December, when some dry cleaners argue that clothes do not get as dirty as during the warmer, summer months. In addition, due to the short duration of the project, it was not possible to develop data on the long-term performance of multiprocess wet: specifically, how clean garments would be after multiple cleanings.

The new wet machine technology was first developed in Europe. The Swedish Aqua Clean System distributed by Wascomat has been operating recently in Germany. This development was spurred in part by the fact that Germany has very strict dry cleaning regulations. Because of these regulations, some German landlords were refusing to lease land to new dry cleaners, or renew leases for existing cleaners, for fear of perc contamination. Some German dry cleaners, who used Wascomat laundry machines in their stores to clean shirts and other washable garments without perc, asked the company to explore perc-free alternatives to dry cleaning. Wascomat has now introduced the Aqua Clean System in North America.[5] Similarly, the Belgium manufacturer Ipso has released the HF234 wet machine.

A privately owned U.S. cleaner who currently operates a shop using only wet machines is Ecomat of New York City. With three locations in Manhattan, Ecomat operates one facility that is both a professional clothes cleaning shop and a laundromat; the two other shops are laundromats and drop sites for professional cleaning. Many of the clothes are cleaned in an Aqua Clean machine such as the kind used in Europe. In addition, Ecomat technicians have access to the coin-operated Wascomat washing machines in the adjoining laundromat. In this manner, Ecomat is capable of processing a larger amount of clothes than could be processed by one wet cleaning machine. This particular set-up will not be specifically analyzed in our study, because it uses multiple wet cleaning machines.

Clothes Cleaning Options

Although this study focuses on professional clothes cleaning, there are a number of alternatives that could be used to clean clothes. Americans clean the majority of their clothes at home (either in washing machines or by hand) or at coin-operated laundromats. When it comes to fine washables, there are three typical approaches: home hand-washing, home machine-washing on the gentle cycle, or paying for professional cleaning. This study does not address the option of not wearing fine washables, which is another alternative to professional cleaning. While this approach is the most environmentally sound alternative to dry cleaning, it requires a major change in social trends, cultural norms, and human behavior. In this study, we are assuming that there is a demand for wearing fine washables, and we are interested in assessing alternative cleaning options.

Home washing is a relatively quick, convenient, and inexpensive option. The consumer can select machine-washing or hand-washing depending on fabric type, time, and access to a washing machine. Laundromats cater to people who do not have washing machines in their homes or who have oversized garments needing larger machines. As opposed to chemical solvents, all three systems use laundry detergent and water.

People choose professional cleaning for several reasons. Many pay for the convenience of having someone else do their laundry. In addition, people generally select professional cleaning for fine washables because they are labeled "dry clean only." Garments that are considered fine washables may include fabrics such as linen, silk, rayon, cotton knits, and woolens; garments with special trims, beads, etc.; and clothes with pleats and intricate tailoring, which require special pressing and finishing. Many of these types of garments have the potential to shrink, bleed, or be otherwise damaged if cleaned in traditional water methods.

Professional cleaning today is predominantly performed using the dry cleaning process. This terminology is misleading in that clothes do not stay "dry." Dry cleaning actually involves immersing the garment in a non-polar liquid solvent which dissolves the organic materials soiling the fabrics. A wide range of solvents has been used for cleaning garments, from gasoline to kerosene to chlorinated and chloroflorinated hydrocarbons. Recent studies estimate that over 80 percent of dry cleaners use the solvent perc, while the remaining use petroleum, CFC-113, and 111-TCE.[6] Perc is the most widely used because of its superior performance characteristics for most fabrics and stains. Perc is virtually non-flammable and dissolves almost all organic stains. Because perc has a low viscosity and low surface tension, it can penetrate fibers to dissolve soils rapidly.

Due to health and environmental concerns, alternatives to perc dry cleaning are being developed in the United States and Europe. New <u>wet machine cleaning</u> clean fine washables with mild detergents, varying degrees of mechanical action, and residual moisture controls to avoid garment damage. <u>Multiprocess wet cleaning</u> is labor intensive because skilled laborers must examine incoming garments and assess the exact cleaning needs of each garment, depending on fabric, types of stains, etc. Multiprocess can involve spotting, gentle hand washing, machine washing, and tumble drying. Some cleaners use both methods: they sort all incoming clothes, using wet cleaning on most garments and perc dry cleaning on those they believe require it due to fabric type or garment construction.

Dry Cleaning Process Description

The cleaning process begins with garment inspection and sorting. Some garments require spotting to remove certain stains. Clothes are then separated into categories based on their cleaning needs. Sorting allows better control of cleaning time and detergent (charge soap) concentrations. Charge soap is a mixture of small amounts of water and detergent; it is added because perc cannot dissolve water-soluble stains such as blood and perspiration. The detergent is used to reduce the surface tension of the water so that it can mix uniformly with the perc and also to assist in removing water-soluble stains.

There are a variety of combinations of machines and emission-control technologies that can be used within a traditional dry cleaning system. Figure 1 (see page 11) is a process flow diagram representative of a common dry cleaning process.

Sorted garments are placed in the dry cleaning machine basket or wheel. Perc enters the wheel of the dry cleaning machine and is mixed with a sizing agent, which aids in restoring body to the garments by increasing strength and smoothness.[7] Charge soap is also added. The garments are agitated through one or more wash cycles. Washing is followed by an extraction cycle, in which the load is spun to remove excess solvent. Upon completion, the drying cycle begins, during which the load is tumble dried in heated air. During the last part of this phase the air is allowed to cool. The purpose is to remove most of the residual perc through condensation in the recovery unit and reduce the temperature of the fabric. During the extraction phase, not all of the perc is extracted from the garments. The amount of residual perc which remains depends in part upon fabric type and drying temperature. (For further discussion, see the Performance section). After the extraction phase the garments are removed and finished by steaming, shaping, and/or pressing.

The recovered solvent is re-used in the next wash cycle. But first, it must be filtered through a cartridge powder or disc filter to remove suspended solids (hair, dirt particles, etc.). Also, the recovered perc is periodically piped to a distillation unit where it is heated to 220 degrees Fahrenheit. The distillation process removes oil, fat, grease, and other impurities that were removed from the garments. The vapors from this process are passed through a condenser. The clean perc is collected and returned to the unit; the water remaining contains perc and must be evaporated, stored in drums for disposal, or, after additional filtration, discharged into the municipal sewer system. The solids filtered from the solvent, called muck, and the sludge at the bottom of the still, called still bottoms, can be further treated to remove perc by azeotropic condensation. The muck and still bottoms are boiled in water to separate the perc. The reclaimed perc is added back into the holding unit. The residual muck, spent filters, and still bottoms are collected for hazardous waste disposal since they still contain perc.

Machines are generally divided into transfer and dry-to-dry types. A transfer machine has separate units for cleaning and drying garments. After garments are cleaned in perc in one machine, the operator physically removes them from the wheel or basket of the wash unit and transfers them to a separate drying unit. In contrast, a dry-to-dry machine performs cleaning, extracting, and drying operations in a single unit — garments are not transferred during the process.

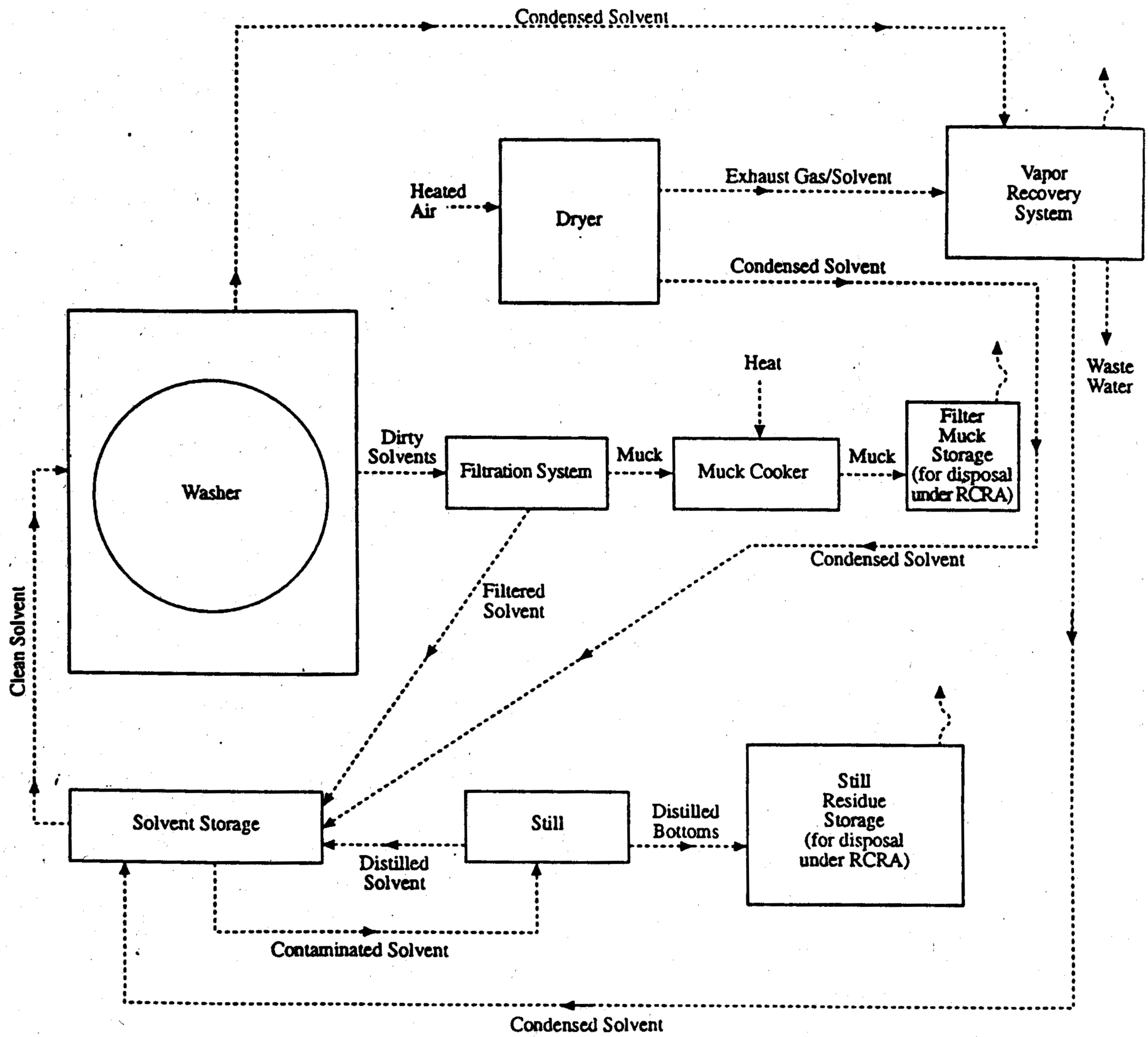
Machines are further characterized according to the type of emission control employed. In a vented machine the dryer exhaust is released to the atmosphere. If a vented machine is fitted with a carbon adsorber or refrigerated condenser, residual solvents can be removed before releasing the air to the atmosphere. Perc is reclaimed from the carbon filters by an operator-initiated process called steam stripping, which passes steam through the filter in reverse. Recovered perc is then added back into the solvent tank.

In a closed-loop machine, the air used for drying is continuously recycled through the machine. Perc is recovered from dryer air by cooling it to below its dew point with a refrigerated condenser. The air is recirculated back into the wheel, and the condensed perc is captured and returned to the solvent tank. Refrigerated condensers are considered to be preferable to carbon adsorbers because their efficiency at removing perc does not rely as heavily on the operator.[8] In addition, cleaning carbon adsorber filters by steam stripping generates more perc-contaminated water than does the refrigerated condenser process.

The distillation bottoms, muck, and used cartridges are classified as hazardous wastes and must be disposed of accordingly. The major sources of perc release associated with dry cleaning are:

- perc retained in filters and muck;
- distillation bottoms;
- dryer exhaust;
- fugitive emissions from leaky pipes, seals, flanges, and pumps;
- transportation spills;
- on-site spills;
- disposal of filters;
- incineration of solvents and filters in cement kilns (disposal method); and
- off-gassing from cleaned clothes.

FIGURE 1 - PROCESS FLOW DIAGRAM FOR DRY CLEANING[9]



Dr. Manfred Wentz, 1994. Fabricare Legislative and Regulatory Educational Organization, "Clearing the Air on Clean Air." The University of Tennessee Center for Industrial Services, Tennessee Department of Environment and Conservation, Video of Teleconference, May 12.

Water-Based Alternative Cleaning System

The water-based alternative system that will be studied in this comparative analysis is a combination of two methods: wet machine cleaning and multiprocess wet cleaning. A brief description of each of these processes follows below. The analysis assumes that, in a water-based alternative cleaning system, roughly 70 percent of fine washables will be cleaned using wet machines, with the remaining 30 percent undergoing multiprocess wet cleaning.[b] In fact, wet machines are currently being used by professional clothes cleaners in several German cities to process 75–85 percent of all garments. These shops do not own perc-based dry cleaning machines.[10] As with dry cleaning, it is assumed that men's shirts are laundered: because the laundering process is the same for both wet and dry cleaners, it is excluded from this analysis.

Wet Machine Cleaning Description[11]

Wet machines are programmed by an operator to achieve precise control over the desired cleaning time, mechanical action, temperature, and extent of water extraction. Proper programming, based on the size, fabric type, and cleaning needs of the individual loads, is critical to the efficiency and effectiveness of the garment cleaning.

Wet machines use a special wet cleaning detergent based on a protein-derived collagen. According to the Aqua Clean Company, its detergent is pH-neutral and biodegradable. Additionally, the detergent has been analyzed by EPA and is unregulated. The detergent removes inorganic stains as well as lipophilic stains. Spotting is still necessary, but only for grease-based lipophilic stains. Like dry cleaning and multiprocess wet cleaning, finishing is required following wet machine cleaning.

Wet machine cleaning also requires specially designed dryers that, in addition to controlling temperature, monitor residual moisture in the clothing. For many fabric types, it is not simply water on garments that causes shrinkage, but the combination of water and heat. Garment shrinkage generally occurs at the end of the drying process when the last 10 percent of the humidity evaporates.[12] Thus, wet cleaners must carefully monitor moisture content to prevent shrinkage. In addition, mechanical action can cause garment shrinkage,

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[b] After six months of operation, Environment Canada's demonstration project, Green Clean, has realized a process flow of 70 percent wet machine cleaned, 25 percent multiprocess wet cleaned and 5 percent deferred for perc cleaning. For simplification we have assumed a process flow of 70 percent wet machine cleaned and 30 percent multiprocess wet cleaned. See Appendix F for a summary of wet cleaning percentage breakdowns for varies practitioners. (Personal communication with Toby Brodkorb, Engineer, Environment Canada, December 12, 1994).

so tumbling in the dryer is done at a high temperature for a short period of time. Three types of technologies control moisture levels in the dryer. Standard dryers, such as the typical dryers used at home, are generally time- and/or temperature-controlled. More advanced dryers used in wet machine cleaning estimate residual moisture by measuring the moisture in the air exhaust of the dryer. Even more sophisticated is the Aqua Clean System dryer, which uses electrical sensors inside the dryer to directly measure residual moisture 400 times per second. This type of control allows the dryer to shut off when the desired humidity level is reached. As with the wet washing machines, the operator of the drying machines programs the dryer according to the characteristics of the clothing load (fabric type, size, water content, etc.) and the desired extent of drying.

Some garments, such as wool suits and double-lined jackets, may require drip drying since machine drying can shrink them. In this respect, wet cleaning would be a more lengthy process. To the extent that customers demand quick processing of clothes, this could be a constraint of wet cleaning. In addition, high-volume cleaners, or cleaners that process high volumes of these types of suits and jackets, may be constrained by the availability of space in which to hang garments to dry.

See Appendix H for a summary report prepared by the Center for Neighborhood Technology on wet cleaning machines. This report includes information on contacts, machine features, and estimated costs for five wet cleaning machine systems.

Multiprocess Wet Cleaning Description[13]

Multiprocess wet cleaning is a method of cleaning clothes in which each garment receives individual treatment. Knowledge of fabric and water interaction is necessary in order to protect the garment during the process. Depending on fabric type and degree of cleaning required, the process uses one or more of the following techniques.

- **Thorough steaming and spotting for garments containing stains and odors.** The spotter applies steam to the entire garment using a steam gun. Steam penetrates the fibers, releases dirt, and dissolves water-soluble particles. A solution of water and spotting solvents may be applied to stains using a paint spray gun and then rinsed with concentrated steam. For stubborn stains, additional spotting chemicals and/or light scrubbing may be applied.

- **Gentle hand washing in soapy water for delicate washable fabrics.** Garments are immersed in a soap-and-water solution. (Garments may be spotted before immersion.) Delicate garments are generally hung to dry. To remove odors, a wet cleaner may hang certain garments in a cedar closet or other specially designed environment.

- **Scrubbing for durable fabrics which are soiled.** A concentrated soap solution and small amounts of water are applied to the fabric, and scrubbed to remove stains.

- **Tumble drying to remove moisture and remove odors.** Garments that are moist and/or malodorous may be tumble dried. This process removes moisture and freshens garments through the use of a fabric softener. Delicate garments are put in net bags to avoid stretching or snagging.

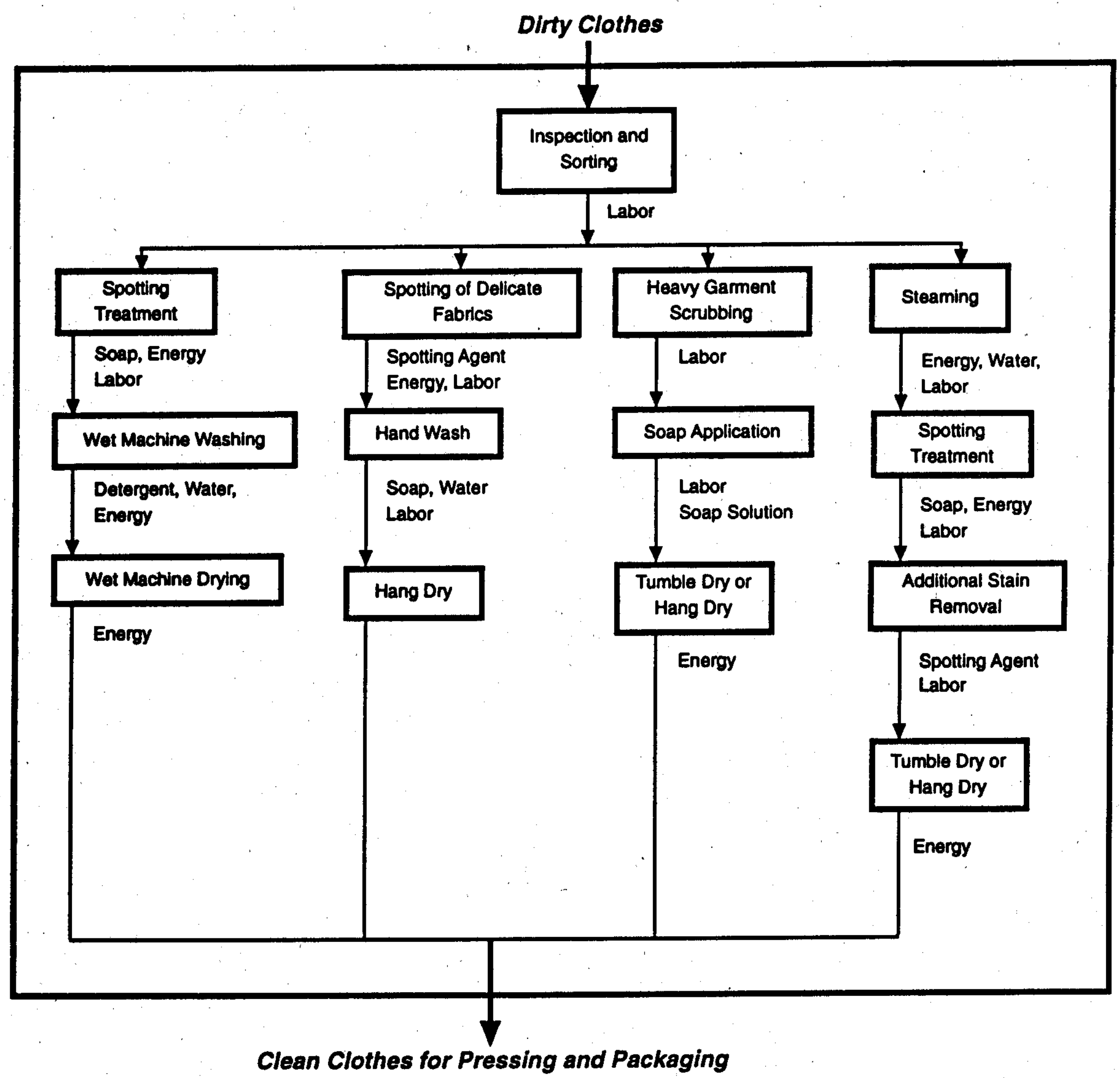
In order to decide which of the above methods to employ, a garment care specialist inspects the clothing for fabric type, fabric stains, and degree of odor. More than one technique may be used. Note that some of these techniques, such as steaming and spotting, are similar for both wet and dry cleaning.

Multiprocess wet cleaning is a broad category of methods with several variations of the above techniques. These variations involve individual judgment, decisions, and innovation based upon experience. Some practitioners of multiprocess wet cleaning use biodegradable spotting solutions, soaps, and detergents to the extent possible. These products are produced from essential oils obtained from plants and flowers. However, some stains cannot be removed with these biodegradable products and require the use of conventional solvent-type agents such as amyl acetate, oxalic acid, peroxide, sodium perborate, and ammonia.

The Environment Canada wet cleaning demonstration project only used nonchlorinated solvents. Similarly, given concern about traditional solvents, Aqua Clean plans to introduce a full line of biodegradable spotting chemicals. In this analysis, we assume that the model facility uses nonchlorinated spotting chemicals and Aqua Safe detergent.

After treatment, all garments are pressed and finished in the same manner employed by traditional dry cleaning. Figure 2 illustrates the process flow for wet cleaning.

FIGURE 2 - PROCESS FLOW DIAGRAM FOR WET CLEANING



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[1]Center for Emissions Control, *Dry Cleaning: An Assessment of Emission Control Options,* p. 10.
[2]Jeff Cantin, "Overview of Exposure Pathways" in *Proceedings: International Roundtable on Pollution Prevention in the Dry Cleaning Industry,* EPA/774/R-92/002 (Washington, November 1992), p. 6.
[3]Ibid.
[4]Personal communication with Ken Meyer, Owner, Meyer's Cleaners, November 4, 1994.
[5]Aqua Clean Systems, Inc., "The Aqua Clean System" (Undated). Seven page-fact sheet provided by Kevin Daly, Product Manager of the Aqua Clean System.
[6]Cantin 1992, p. 5; Source Reduction Research Partnership, Metropolitan Water District of Southern California, and Environmental Defense Fund, *Source Reduction and Recycling of Halogenated Solvents in the Dry Cleaning Industry: Technical Support Document* (undated).
[7]Grace G. Denny, *Fabrics,* Seventh Edition, (Philadelphia: J.B. Lippincott Company, 1953): 163.
[8]Personal communication with Katy Wolf, Director, Institute for Research and Technical Assistance, March 5, 1995.

[9]Dr. Manfred Wentz, Fabricare Legislative and Regulatory Educational Organization, "Clearing the Air on Clean Air," The University of Tennessee Center for Industrial Services, Tennessee Department of Environment and Conservation, video of teleconference (May 12, 1994).
[10]Aqua Clean Systems, Inc., p. 6.
[11]This description is drawn from the following document: Wascomat, "Announcing the Aqua Clean System - An Environmentally Safe Method of Garment Care" (August 1, 1994). It also relies upon descriptions of the wet cleaning system implemented as part of the Environment Canada demonstration project. Suppied by Toby Brodkorb, Environment Canada engineer, in personal communication dated December 12, 1994.
[12]Aqua Clean Systems, Inc., p. 4–5.
[13]The description below is drawn from the following document: U.S. EPA, *Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process*, EPA 744-R-93-004, (Washington, DC, September 1993).

III. METHODOLOGY

This study is a multicriteria comparative analysis of a traditional perc dry cleaning process and an alternative wet cleaning process. The two cleaning methods are analyzed and compared with respect to five evaluation criteria: human health impacts, environmental impacts, performance capability, economic factors, and applicable regulations. Background research for this analysis involved a comprehensive review of industry issues. Original research included telephone and in-person interviews of dry cleaners, wet cleaners, industry representatives, machine manufacturers, regulatory agencies, and environmentalists.

In performing this comparative analysis, we have applied, in a limited fashion, evaluative tools from the existing Life Cycle Design and Life Cycle Assessment methodologies.[1,2] Our comparative analysis organizes the data into a comprehensive framework that includes all aspects a commercial dry cleaner would consider when choosing cleaning methods and technologies. Furthermore, the framework provides a useful means by which to input and interpret new information as it becomes available. The application of selected techniques from Life Cycle Design and Life Cycle Assessment also promotes a scientific and objective analysis.[3]

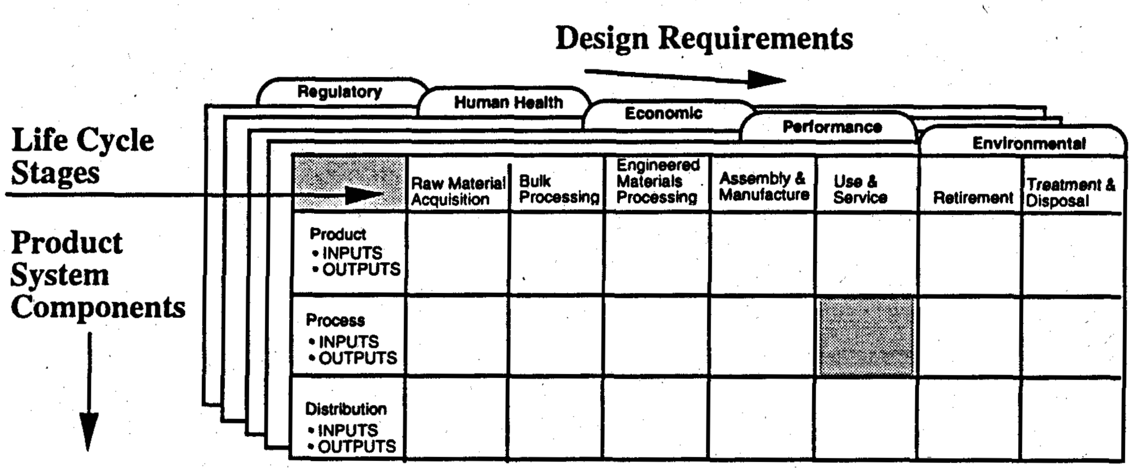
Life Cycle Design

Life Cycle Design is a framework that provides guidance for integrating environmental concerns into the design and management of product's life cycle, which consists of the following *life cycle stages*[4]

- raw material acquisition
- raw material bulk processing
- engineered materials processing
- product assembly and manufacture
- product use and reuse
- product retirement
- product treatment or disposal

At each stage, inputs (such as material and energy) are consumed and outputs (such as production by-products and other wastes) are released. Inputs and outputs from each stage result in potential ecological and human health effects. These inputs and outputs are further categorized into the three *product system components* : product, which tracks the product material; process, which includes all steps that transform the product material; and distribution, which involves the transportation of the product material between stages. Utilizing life cycle stages and product system components, the Life Cycle Design methodology facilitates a systematic examination of the interaction of environmental requirements with other product requirements such as performance, human health, cost, and regulatory requirements. Life Cycle Design is conceptually represented in Figure 3.

FIGURE 3 - CONCEPTUAL LIFE CYCLE DESIGN REQUIREMENTS MATRICES [5]



The layers in the file folder diagram represent organizational matrices for each requirement. For our analysis, we modified a set of matrices developed by the National Pollution Prevention Center for Higher Education (NPPC). In the original NPPC diagram, the "Environmental" matrix covers both ecological and human health impacts; in our analysis, "Human Health" and "Environmental" are separate matrices, with the latter focusing on environmental fate and transport as well as resource depletion and ecological issues.[c]

The matrices' columns (for life cycle stages) and rows (for product system components) organize the interrelated data for analysis and evaluation. These matrices provide a logical framework for considering the full range of stakeholder requirements. An appropriate application of the framework will assist in identifying interactions and trade-offs among life cycle stages, product components, and stakeholder requirements such as performance and cost. Furthermore, by applying this tool, designers can help prevent shifting impacts between media (air, land, water) and between other life cycle stages.[6]
Figure 4 is a conceptual model illustrating a sample of the activities that occur within each

[c]In creating the original category of "Human Health", we have eliminated the NPPC's original Life Cycle Design Matrix category of "Cultural," instead addressing "Cultural" issues under "Performance."

stage of the life cycle of clothing. All activities within the life cycle result in impacts. However, for the purpose of this comparative analysis, we will define the system under investigation as the professional clothes-cleaning process component within the use/ reuse/ maintenance stage of clothing. This system is highlighted in Figure 4, and its boundaries are discussed in further detail in the Process Descriptions and the Parameters sections. Furthermore, we will apply the Life Cycle Design tool of multiobjective analysis by examining performance, human health, cost, and regulatory criteria in addition to environmental criteria. These criteria will form the basis of our comparative analysis of traditional perc dry cleaning and an alternative wet cleaning method.

Life Cycle Assessment

This comparative analysis also applies specific tools from Life Cycle Assessment. The following is a brief discussion of the Life Cycle Assessment process steps.

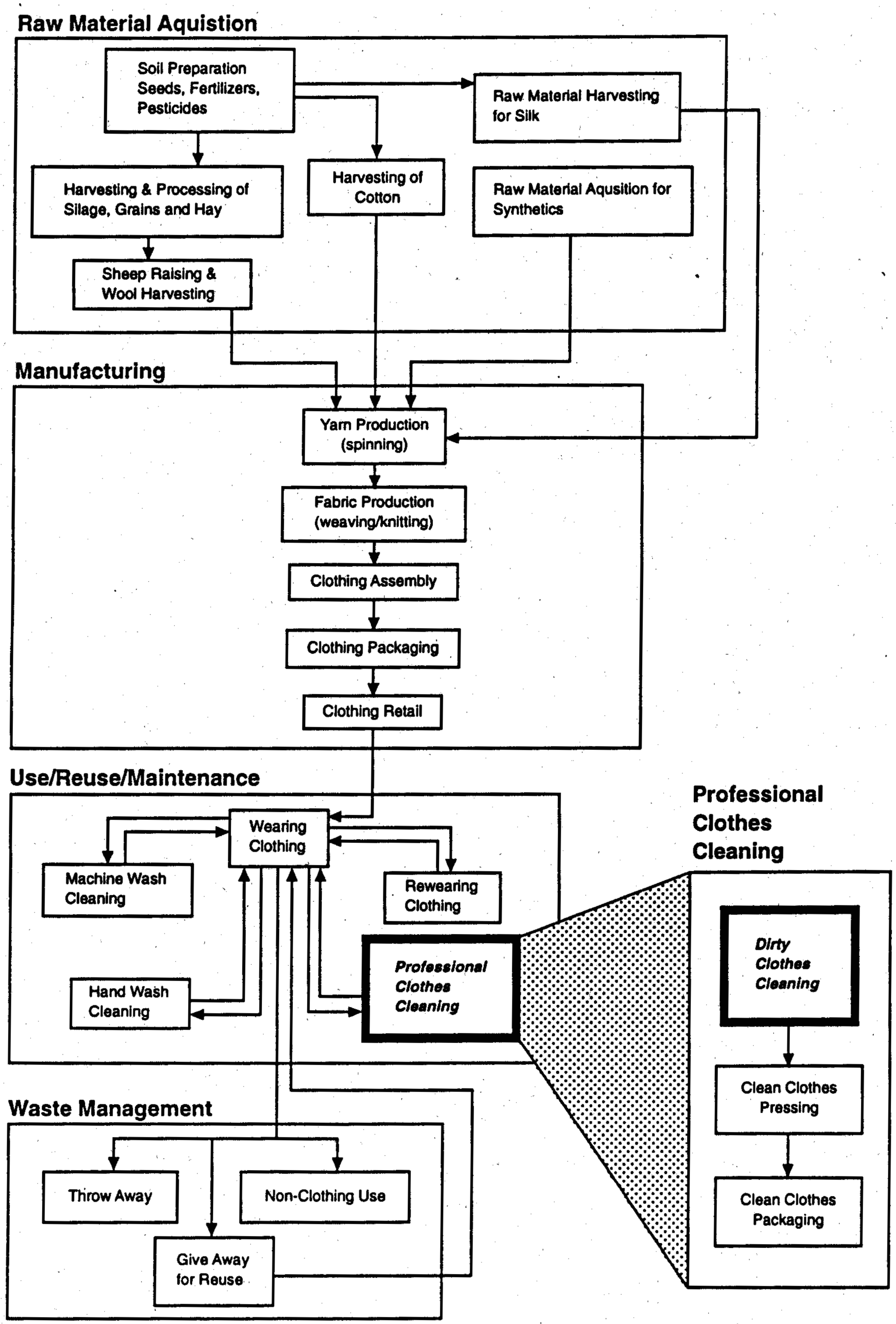
Inventory Analysis: All the inputs and outputs of a product system during all stages o f its product life cycle are identified and where possible quantified.

Impact Assessment: This quantitative and/or qualitative process characterizes and assesses the effects of the environmental burdens identified in the Inventory Analysis.[7] It links the inputs and outputs identified during the inventory analysis to their resulting impacts by answering the following question: "What are the significance and consequences of the input and output items with respect to ecological and human health?"

Improvement Analysis: Having used an inventory analysis and an impact assessment to develop an understanding of the product system under investigation and its environmental impacts, an improvement analysis then focuses on identifying opportunities for reducing environmental impacts.

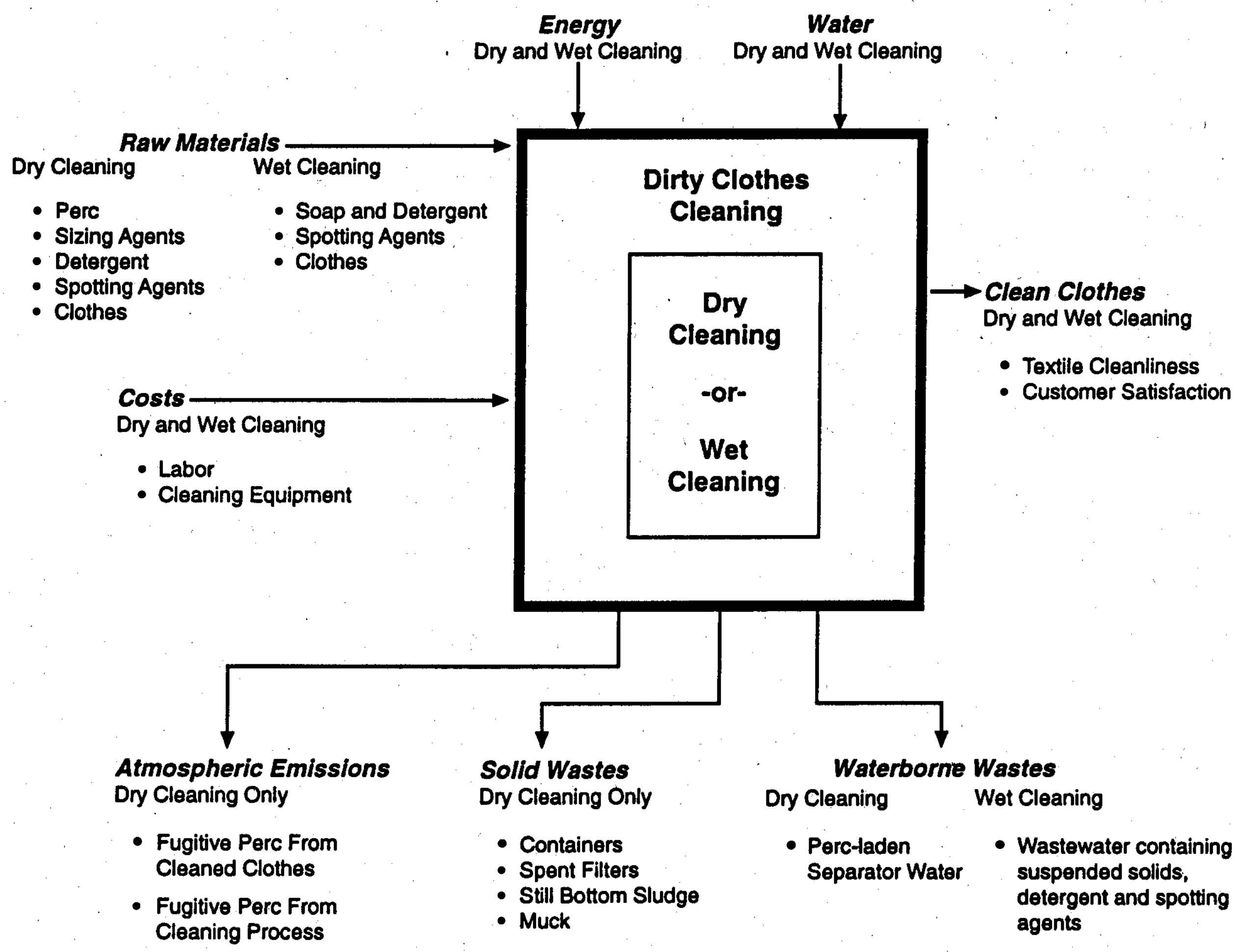
This study performs an inventory analysis and an impact assessment on the process of professional clothes cleaning as defined within the life cycle of clothing (Figure 4). We applied these evaluative techniques in a limited fashion due to the lack of comprehensive data on all inputs and outputs of the clothing life cycle. Thus, this study does not represent a rigorous Life Cycle Assessment.

FIGURE 4 - LIFE CYCLE OF CLOTHING



Inputs and outputs are quantified to the extent possible for the two specific professional clothes-cleaning processes considered in this study, and their resulting impacts are analyzed. Figure 5 is a template which illustrates the primary inputs and outputs of the professional clothes-cleaning systems which are being compared in this study (i.e., perc-based, closed-loop, dry-to-dry cleaning and water-based, wet machine and Multiprocess wet combination cleaning). The specific details of the inputs and outputs are further defined in the following Parameters section.

FIGURE 5 - INVENTORY ANALYSIS FOR GARMENT CLEANING INPUTS AND OUTPUTS



Parameters

As discussed in the Methodology section, in order to ensure this study is of a manageable size without sacrificing information necessary to meet the study's objectives, it is important to narrow the focus by defining clear boundaries. The perc-based and water-based cleaning systems under comparison are based on a typical, commercial cleaner with an annual sales volume of $5,000 per week. For the purposes of this analysis, a commercial dry cleaner is defined as an independently operated neighborhood or franchise shop (the most common type of dry cleaner)[8] as opposed to an industrial facility or coin-operated unit. Also, as mentioned earlier, because we are interested in exploring the difference between wet and dry cleaning, we excluded the water-based laundering that both types of cleaning establishments typically use for items such as men's dress shirts.

The final stage of the cleaning process is garment finishing. In researching this study, we found varying opinions on whether garment finishing would be more labor intensive in wet cleaning than dry cleaning. The economic consequences of the difference will be discussed in the economic analysis.

We have based our analysis of dry cleaning is based on perc because it is the most widely used of the solvents available for dry cleaning.[9] This study uses as its standard a 50-pound dry-to-dry, closed-loop unit with a refrigerated condenser. While this technology is not currently being used by the majority of cleaners today[10], new federal regulations will soon require most dry cleaners to install either refrigerated condensers or carbon adsorbers; the former are generally viewed as preferable because the latter must be steam flushed, creating perc-contaminated wastewater. The International Fabricare Institute recently proposed amending dry cleaning laws to require all new dry cleaning systems be dry-to-dry with refrigerated condensers, at a minimum.[11] Our study assumes that the machine is operated at 90 percent of capacity and can clean 30,000 pounds of clothes per 55-gallon drum of perc. The transfer machine will not be examined as it is used by only 30 percent of U.S. commercial dry cleaners[12] and is being phased out under new NESHAP regulations.

This study analyzes a wet cleaning system that involves sorting the fine washables and processing approximately 30 percent using labor-intensive multiprocess wet cleaning and 70 percent by wet machine cleaning. (This breakdown is discussed in more detail in the previous description of the wet machine cleaning. The machine that this study uses as its standard is a 50-pound Aqua Clean washing machine with 30-pound drying unit.

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[1]B. W. Vigon et al., U.S. EPA Office of Research and Development, Risk Reduction Engineering Laboratory, *Life Cycle Assessment: Inventory Guidelines and Principles* (Cincinnati: U.S. EPA, 1993).
[2]Society of Environmental Toxicology and Chemistry, *Guidelines for Life-Cycle Assessment: A "Code of Practice"* - SETAC Workshop, (Pensacola, FL: SETAC 1993).
[3]B. W. Vigon et al. 1993.

[4]G.A. Keoleian and D. Menerey, "Sustainable Development by Design: Review of Life Cycle Design and Related Approaches," *Air and Waste* 44 (May 1994):646.
[5]G.A. Keoleian and D. Menerey, Office of Research and Development, Risk Reduction Engineering Laboratory, *Life Cycle Design Guidance Manual: Environmental Requirements and the Product System,* (Cincinnati, OH: U.S. EPA, 1993): p. 44. Reprinted with modifications.
[6]Keoleian and Menerey 1994, p. 646.
[7]Ibid.
[8]Katy Wolf, "Case Study: Pollution Prevention in the Dry Cleaning Industry: A Small Business Challenge for the 1990s," *Pollution Prevention Review* (Summer 1992): 312.
[9]John Bergin, ed., U.S. EPA, *Proceedings: International Roundtable on Pollution Prevention and Control in the Dry Cleaning Industry*, EPA/774/R-92/002 (Washington, November 1992): 5; Source Reduction Research Partnership, Metropolitan Water District of Southern California and the Environmental Defense Fund, *Source Reduction and Recycling of Halogenated Solvents in the Dry Cleaning Industry Technical Support Document*, (Pasadena: Jacobs Engineering Group, 1992): 5.
[10]Radian, *Documentation of Growth Rates for the Dry Cleaning Industry*, Memorandum to dry cleaning NESHAP file, (Radian Corporation, March 29, 1991). As cited in Bergin, ed. *Proceedings* 1992, p. 7.
[11]William E. Fisher, "Current Pollution Prevention Initiatives: An Integral Part of the Industry's CERCLA Amendment," (November 9, 1994). This paper was one of written summaries of agenda items discussed on October 24, 1994, in a meeting between dry cleaning industry associations and the U.S. EPA. This paper was an enclosure in a letter to David Doniger, U.S. EPA Office of Air and Radiation, from Brooksher Banks, FLARE Director. Fisher is Senior Vice President of the International Fabricare Institute.
[12]Wolf, p. 314.

IV. INVENTORY ANALYSIS

Industry Sector Inventory

This study quantifies the inputs and outputs of the garment cleaning process for both the industry as a whole and an individual garment cleaning establishment. Throughout the analysis multiple sources are cited to provide as much information as possible. The data cited represent industry standards for quantifying dry cleaning inputs and outputs.

Table 1 summarizes industry-wide data from two sources: the Source Reduction Research Partnership (SRRP) and the EPA. The Individual Process Inventory which follows discusses in detail reasons for variations in quantities of perc used, air emissions, and solid waste.

TABLE 1 - INDUSTRY-WIDE DATA FOR PROFESSIONAL CLEANING [1, 2]

Inputs and Outputs	SRRP 1988		EPA/774/R-92/002 1991	
	Metric Tons	English lbs. (thousands)	Metric Tons	English lbs. (thousands)
Perc Used	134,190	295,298	130,100	286,220
Air Emissions				
Vent	51,970	114,334		
Fugitive	52,560	115,632		
Fugitive Transfer	12,620	27,764		
Total	117,150	257,730	87,000	191,400
Solid Wastes	17,040	37,488	43,100	94,820
Water	negligible	negligible	negligible	negligible

Table 2 is an industry profile by type of professional perc dry cleaner. It is important to note that the SRRP data reflect the number of cleaners whereas the EPA data list number of machines. Additional EPA data indicate that the number of commercial dry cleaning machines has remained steady between 1987 and 1991, while the number of industrial and coin-op machines has declined.[3]

TABLE 2 - INDUSTRY PROFILE FOR PROFESSIONAL CLEANING [4, 5]

Industry Profile	SRRP 1988		EPA/774/R-92/002 1991	
	# of Cleaners	% of Total	# of Machines	% of Total
Type of Perc Cleaner				
Commercial	14,348	76%	31,434	91%
Coin-Operated	4,300	23%	3,044	9%
Industrial	251	1%	130	0%
Total	18,899	100%	34,680	100%

Data on the number of perc cleaners and the number of perc machines vary depending on the methodology used to estimate these figures. In Table 2, SRRP estimates are based on the U.S. Department of Commerce's "County Business Patterns for the United States" for 1986. These figures are based solely on payroll figures for dry cleaners. Since many dry cleaners are small businesses operated by owners, or owners and family members, they are not reflected in payroll data. As a result, the SRRP estimates for number of commercial perc-using cleaners are most likely understated.[6] We, however, have included these in this study because they represent industry standard data which are often referenced when quantifying dry cleaning inputs and outputs. Furthermore, these data when compared to the 1991 data assist in illustrating acknowledged trends over time in the dry cleaning industry.

The EPA data were developed in 1991 as part of the EPA's efforts under the 1990 Clean Air Act Amendments to regulate the air emissions of perc from dry cleaning facilities.[7] The information was derived from U.S. Census data, yet has been adjusted, based on best estimates, to include those machines used by non-payroll dry cleaners.[8] For these reasons, this information is more current and most likely more accurate than the SRRP data. In addition, the 1991 EPA report estimates that these 31,434 machines are owned by 27,332 individual firms (a firm may own more than one machine).[9] As with the SRRP data, these data are often cited as industry standards.

The International Fabricare Institute (IFI) estimates there are approximately 30,000 operating plants in the retail dry cleaning industry. Safety-Kleen estimates that there are between 30,000 and 35,000 dry cleaning plants. The Census of Service Industries considers a "plant" to be any facility where cleaning takes place.[10] The number of "plants" may differ from the number of "cleaners" or "firms" because a "cleaner" may operate more than one "plant." Furthermore, it is unclear as to whether all of these "plants" cited by IFI and Safety-Kleen use the solvent perc. In order to avoid confusion due to the ambiguity of these terms and figures, we have opted to describe the size of the commercial industry in terms of the number of perc machines in operation and will defer to the 1991 EPA estimates of 31,434 commercial perc machines in operation.

Table 3 breaks down the industry wide data presented in Table 1 for the commercial sector. Again, the Individual Process Inventory section which follows discusses in detail reasons for variations in quantities of perc used, air emissions and solid waste. Figure 6 is a conceptual representation of the data utilizing the Life Cycle Assessment Inventory Diagram (See Methodology, Figure 5).

TABLE 3 - COMMERCIAL SECTOR-WIDE DATA FOR PERC DRY CLEANING [11, 12]

	SRRP 1988			EPA/774/R-92/002 1991		
	Metric Tons	English lb (thousands)	% of Total for All Sectors	Metric Tons	English lb (thousands)	% of Total for All Sectors
Clothes Cleaned (*)	1,209,182	2,620,200		1,022,500	2,249,500	
Perc Used	119,100	262,020	89%	122,700	269,940	94%
Air Emissions						
Vent	44,070	96,954	38%			
Fugitive	47,640	104,808	41%			
Fugitive Transfer	11,910	26,202	10%			
Total	103,620	227,964	88%	81,800	179,960	94%
Solid Wastes	15,480	34,056	91%	40,900	89,980	95%
Water	negligible	negligible		negligible	negligible	

(*) This number is an estimate and is reported to add context. It is derived from (1) total perc used, and (2) a conversion for perc usage (SRRP: 10 lb perc/100 lb clothing, EPA: 12 lb perc/100 lb clothing).

FIGURE 6 - INVENTORY DIAGRAM FOR ALL COMMERCIAL, PROFESSIONAL CLEANERS[13]

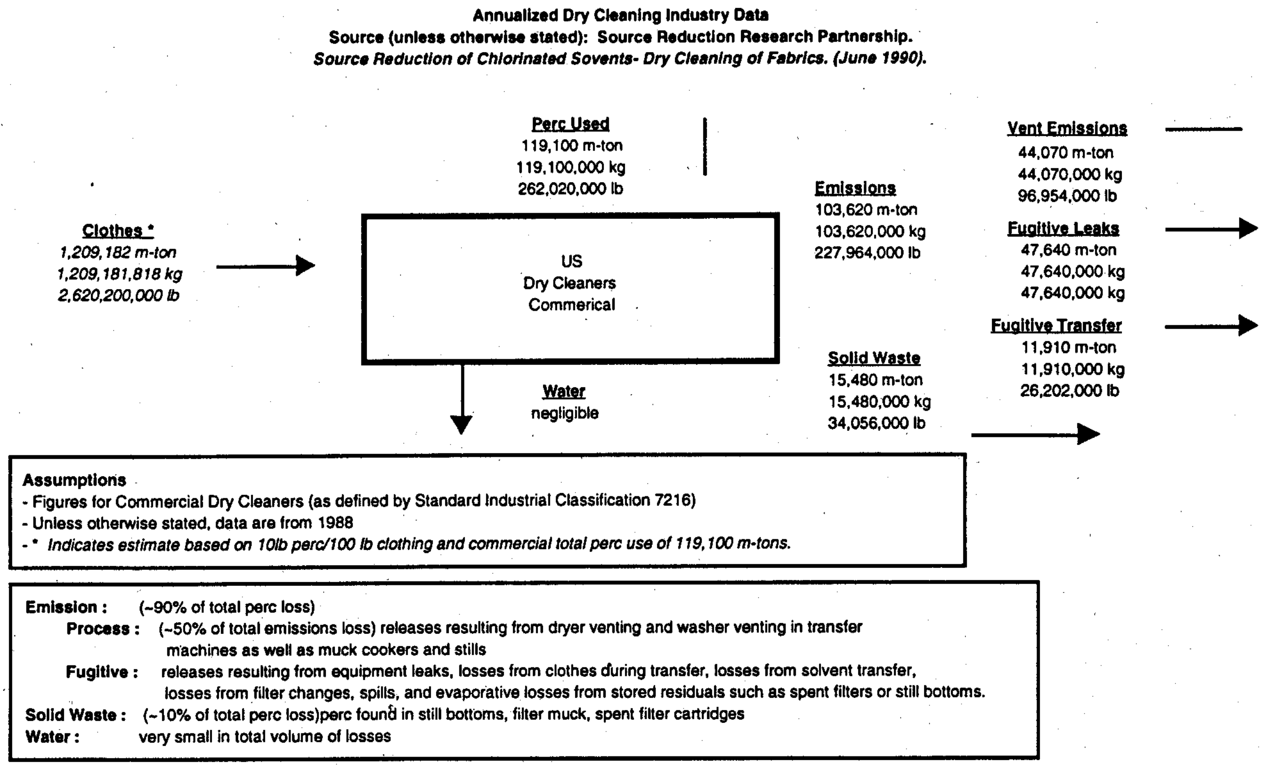

Table 4 breaks down the commercial industry sector further by technology. Again, the SRRP data reflect the number of cleaners whereas the EPA data list number of machines.

TABLE 4 - COMMERCIAL SECTOR PROFILE — MACHINE TYPE[14, 15]

	SRRP 1988		EPA/774/R-92/002 1991	
	# of Cleaners	% of Total	# of Machines	% of Total
Machine Type for Commercial Cleaners				
Transfer	4,878	34%	10,311	33%
Dry to Dry	9,470	66%	21,395	67%
Total	14,348	100%	31,706	100%
Type of Vapor Control for Commercial Cleaners				
Refrigerated Condenser	1,435	10%	14,774	47%
No Vapor Control	7,174	50%	10,059	32%
Carbon Adsorber	5,739	40%	6,601	21%
Total	14,348	100%	31,434	100%

Table 5 lists emission factors for the commercial, dry-to-dry refrigerated condenser technology. These factors will be discussed further in the following Individual Process Inventory.

TABLE 5 - COMMERCIAL SECTOR PROFILE — CONDENSER TECHNOLOGY[16, 17]

	SRRP 1988		EPA/774/R-92/002 1991	
	lb perc/100 lb clothes	kg perc/ 45.5 kg clothes	lb perc/100 lb clothes	kg perc/ 45.5 kg clothes
Conversion Factors				
Process Emissions	1.6	0.72	0.44	0.09
Solid Waste Generation	0.6	0.28	2.4	1.10
Fugitive Emissions	2.1	0.94	2.4	1.10
Water				
Total	4.3	1.94	5.2	2.29
Control Effectiveness of Process				
Process	70%		93.6%	
Solid Waste	70%		0.0%	
Fugitive	70%		51.7%	

Individual Process Inventory

This section identifies the primary resource inputs and outputs of both the dry and wet cleaning processes. Only the actual cleaning of fine washables is addressed. Manufacture of the cleaning agents and the machine equipment is not considered. Garment finishing procedures are assumed to be the same regardless of the cleaning method used.

Table 6 quantifies the primary inputs required and outputs produced for both a dry and wet cleaning system to process the yearly volume of clothes we have assumed. This inventory pertains to a closed-loop, dry-to-dry perc cleaning machine, and a wet cleaning system using a combination of wet machine technology that processes 70 percent of the fine washable garment stream and multiprocess wet cleaning which processes the remaining 30 percent. Inputs identified are the cleaning agents, electricity, and water requirements. Outputs include air, solid waste, and waterborne emissions. Following Table 6, the assumptions behind these numbers are discussed. Calculations are given in Appendix A.

TABLE 6 - YEARLY INPUTS AND OUTPUTS OF DRY AND WET CLEANING SYSTEMS

	Dry Clean	Wet Clean
Inputs:		
Cleaning Agents other than water	45 – 240 gallons perc, 79 gallons detergent	46 – 135 gallons detergent, spotting agents
Electricity	14,136 kWh	6,338 kWh
Water	66 gallons	219,531 gallons
Outputs:		
Air Emissions*	2271 – 2958 lbs. perc	none
Solid Waste†	480 – 1919 lbs. (hazardous waste)	negligible
Waterborne Waste	0.066 – 1.87 lbs. perc in separator water	water, suspended solids, and detergent components

* The lower figure is based upon U.S. EPA emission factors (EPA/774/R–92/002. 1992). The higher figure is based upon emission factors from the Source Reduction Research Partnership. (June 1988).
† The lower figure is based upon dry cleaning emission factors from the Source Reduction Research Partnership. (June 1988). The higher figure is based upon U.S. EPA dry cleaning emission factors (EPA/774/R–92/002. 1992).

Process Inputs and Outputs - Dry Cleaning

Many different dry cleaning machine types and emission control technologies exist. Each system may vary in the amount of energy, perc, and water required, and produce different levels of emissions. The figures in Table 6 represent one typical dry-to-dry perc machine with a refrigerated condenser. This type of machine is considered to be modern dry cleaning technology, employing some of the best available equipment for minimizing perc losses to the atmosphere and reducing the amount of perc used. The inventory numbers would change substantially if different machine technology were analyzed. Many transfer type machines are still in use. In addition, many dry-to-dry machines are still used which do not employ a refrigerated condenser or carbon adsorber to control emissions. These machines would emit a higher amount of perc to the atmosphere, while capturing less in the form of solid waste. They would also require less electricity to operate since they contain no emission control technology. The numbers contained in Table 6 are based on the assumptions below. A full explanation of the first, third, and fourth assumptions is included in the Economic Analysis section.

Dry Cleaning Assumptions:

- the facility processes 79,958.2 pounds of clothes per year;
- the dry cleaning machine is a 50 lb. dry-to-dry closed-loop machine with a refrigerated condenser and carbon cartridge filters for solvent distillation;
- the facility processes 35 loads of clothes per five day work week;
- one load requires 45 minutes to process;

Perc Requirements of the Dry Cleaning Process: Perc mileage is the amount of clothes cleaned per unit of perc (usually per gallon). Mileage varies depending upon machine type, emission control technology, filtration system, and housekeeping practices. Well maintained machines with modern emission control equipment use less perc per unit of clothing. In contrast, older machines or those with leaky seals and gaskets will experience higher losses of perc, using more per unit of clothing. Perc mileage for a dry-to-dry machine with a refrigerated condenser ranges from less than 350 pounds of clothes per gallon to almost 1000 pounds of clothes per gallon.[d] One manufacturer indicates that their solvent distillation system will result in mileage of 1800 pounds of clothes per gallon of perc.[18]

An EPA study utilizing a machine such as the one mentioned above uses a mileage factor of 30,000 pounds of clothes per 55 gallon drum, or 545.45 pounds per gallon.[19] A follow up conversation with EPA indicates this is a representative figure to use for perc mileage since it was obtained by actually monitoring a machine.[20] Using this mileage factor, a dry cleaning operation that processes 79,958.2 pounds of garments a year would require 146.6 gallons of perc. This figure falls within the range given in Table 6. The low figure in this range results from a dry cleaning machine with a mileage of 1800 pounds of clothes per gallon. The high range results from a machine obtaining 333 pounds of clothes per gallon of perc.

[d]For example, Dow Chemical reports that perc mileage for a dry-to-dry machine with a refrigerated condenser will range from 333 to 500 pounds of clothes per gallon. (See Dow Chemical Company, *A Basic Handbook for Dry Cleaners*). A dry cleaner in the Ann Arbor, MI, area using a similar machine reports 700 to 800 pounds of clothes per gallon.

Energy Requirements of the Dry Cleaning Process: Electricity is needed to power the machine as well as associated emission control equipment.

Dry Cleaning Machine: To identify electricity requirements, electrical specifications from the following four machines were used. Each machine is a dry-to-dry, closed-loop machine, with a refrigerated condenser, still, and either disc or cartridge filters.[21]

- VIC Model 1250FS (50 lb.): 28 amps at 240 volts;
- UniClean 50 (50 lb.): 24 amps at 240 volts;
- BOEWE PASSAT/Permac Model P546 (46 lb.): 31 amps at 220 volts; and
- Multimatic Shop Star 400 (55 lb.): 32 amps at 220 volts.

Thus, an average of 28.75 amps and 230 volts is used. Based upon assumed activity level, computations yield 173.58 kilowatt hours per week (kWh/wk) of electricity use for an average 50-pound dry cleaning machine.[22] On a yearly basis, the electricity requirement for the dry cleaning machine is 9,026.16 kWh. Appendix H gives further information on these machines as well as other wet cleaning machines now available in the United States.

Emission Control Equipment:[e] A refrigerated chiller is required to recycle the water used to cool the refrigerated condenser unit during those times of the year when the outdoor temperature is higher than 60° F. When the temperature falls below this, a smaller machine, called the aerocooling unit, is used to meet the cooling requirements of the refrigerated condenser. The aerocooling unit requires significantly less energy than the refrigerated chiller. Each machine turns on and off during the dry cleaning cycle, as needed.

For the refrigerated chiller, we consider a typical 7.5 ton chiller with an average electrical specification of 33 amps at 208 volts, which runs for 5.25 hours per day.[23] Using these figures, the electricity demand is 36.04 kWh/day. Assuming the chiller is required for 26 weeks per year, the yearly energy requirement for this item is 4,685.2 kWh.

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[e]Janet Hickman of Dow Chemical commented that the emission controls on this particular machine may not be representative of many of the newer dry-to-dry refrigerated condenser machines being used today. Ms. Hickman indicated that some newer machines operate more efficiently, thus reducing electricity requirements (Janet Hickman, written comments on a draft, The Dow Chemical Co., TS&D, (March 14, 1995)). A follow-up conversation with Steve Harris, Head Engineer of Vic Manufacturing, verified that there are several variations in emission control technology, but stated that he believed a wet cleaning machine would require less electricity than a dry-to-dry machine using refrigerated condensers and chillers (Personal communication with Steve Harris, Head Engineer, Vic Manufacturing, 1995).

During the remaining 26 weeks, the aerocooling unit is used. The typical electric load for a 7.5-ton unit is 3 amps at 208 volts. Assuming it runs 5.25 hours per day, the energy requirement would be 3.27 kWh/day and 425.10 kWh for the remaining 26 weeks of the year.

Total: The total energy requirements for the dry cleaning system is the sum of requirements for the above individual units. Adding these totals yields a figure of 14,136.46 kWh of electricity required per year to operate the dry cleaning machine.

Additional energy is required in the form of natural gas to operate the boiler in a dry cleaning facility. A discussion of this is included at the end of the inventory section.

Water Requirements of the Dry Cleaning Process: Small amounts of water are required during the dry cleaning process as part of the detergent charge added to perc and also in the refrigerated chiller which recycles the water used to cool the perc in the refrigerated condenser unit.

Detergent Charge: The amount of water required for the detergent charge is obtained from EPA, and based upon VIC Model 1250FS machine specifications.[24] Given the amount of clothes cleaned, along with the assumption that 0.5 percent of the cleaning solvent mix is the detergent and water charge, 53.63 gallons of water per year are required for detergent charge per machine.

Refrigerated Chiller: The 7.5-ton chiller mentioned previously would use an additional 12 gallons of water per year, all of which is recycled within the unit.

Total: The total water required per year to operate the dry cleaning machine is 65.63 gallons.

Additional Inputs into the Dry Cleaning Process: The dry cleaning process uses detergent as part of the charge. U.S. EPA estimates that 79.96 gallons per year of this detergent are consumed for a typical dry cleaning machine such as the one being considered in this study.[25]

Air Emissions from the Dry Cleaning Process: During the dry cleaning process, perc is emitted into the air. Use of the latest emission control technology significantly reduces air emissions. However, perc vapors are still released through process emissions, which include losses from muck cookers and stills, as well as through fugitive emissions such as those resulting from equipment leaks, solvent transfer, filter changes, and spills. Process emissions also result from stored residuals such as spent filters. Table 6 indicates that 2271 to 2958 pounds of perc are emitted into the atmosphere each year in order to process the volume of garments we have assumed. These figures are based upon national emission factors from a commercial, dry-to-dry, refrigerated condenser machine. The low end of this range reflects an emission factor identified by U.S. EPA of 0.44 pounds of process emissions and 2.4 pounds of fugitive emissions of perc per 100 pounds of clothes.[26] The high end of the range is based upon emission factors provided by the Source Reduction Research Partnership for the same type of machine of 1.6 pounds of process emissions and 2.1 of fugitive emissions per 100 pounds of clothes.[27]

One problem in applying these emission factors to an individual machine is that they vary depending upon the specific unit and the extent of handling care and maintenance employed by the machine operator. Variations in emission factors also result from different definitions of wastes, different storage practices of perc materials, and different accounting methods for determining emissions.

Solid Waste Outputs of the Dry Cleaning Process: Outputs produced by the dry cleaning system include perc-contaminated products such as still bottoms, muck, and spent cartridge filters. Each of these outputs is classified as hazardous waste and must be disposed of accordingly. Table 6 indicates that from 480 to 1919 pounds of solid waste are produced per year in order to process the activity level we have assumed. These figures are based upon solid waste emission factors from a typical commercial, dry-to-dry, refrigerated condenser machine. The low end of this range reflects a solid waste generation factor identified by the Source Reduction Research Partnership of 0.6 pounds of perc per 100 pounds of clothes,[28] while the high end of the range is based upon a generation factor provided by U.S. EPA for the same type of machine of 2.4 pounds of perc per 100 pounds of clothes.[29] Reasons why this range is so wide stem from differences in calculating solid waste output. Some sources include the weight of the materials that contain perc, while others include only the weight of perc itself. In addition, some sources assume a different lifetime for filters than other sources.

Filters: A machine such as the one under analysis holds two cartridge canisters, each containing six standard carbon-core filters, as well as two double all-carbon filters, for a total of 14 filters. This is based on a VIC Model 1250FS machine as described by EPA.[30] Each of the six carbon-core filters in the cartridge requires replacement after 1,200 to 1,400 pounds of clothes have been cleaned. Thus, one full canister requires replacement after 7,200 to 8,400 pounds of clothes are cleaned. The double all-carbon filters are generally replaced at the same time as the cartridge. Therefore, after approximately 7,800 pounds of clothes have been cleaned (the midpoint between 7,200 and 8,400 pounds), a total of eight filters will require disposal. At the activity level we have assumed, 10.25 replacements are required per year. Each of the 10.25 replacements consists of eight filters: the six carbon core-filters in the two cartridges, and two double all-carbon filters. Thus, a total of 82 filters are required throughout the year. Data on the weight of each filter were not available.

Still Bottoms: Still bottoms produced during the dry cleaning process must be disposed of as hazardous waste. EPA provides a range of estimates of still bottom generation from 0.5 gallons per 1,000 pounds of clothes cleaned to 3.0 gallons per 1,000 pounds of clothes cleaned.[31] It appears that some sources account for lint disposal weight within this range while others do not. At the low end of the range, the dry cleaning machine would produce 39.98 pounds of still bottom waste per year. At the high end, 239.87 pounds of still bottoms would be produced.

Waterborne Wastes from the Dry Cleaning Process: As mentioned above, a small amount of water is used for the detergent charge. The water is removed from the perc using a separator, and is then disposed. The usual method of disposal is into the sewer system. Another method is to have the separator water hauled away by a licensed disposal company. U.S. EPA reports that over the course of a year, 0.066 to 1.87 pounds of perc may be discharged with the separator water.[32]

Process Inputs and Outputs - Wet Cleaning

Comprehensive wet cleaning data utilizing sophisticated machines and multiprocess wet cleaning methods are not available due to the short history of the technology. The Environment Canada project now underway is monitoring energy and water inputs of their wet cleaning system, which uses an Ipso HF234. Until figures from this demonstration project are fully collected and analyzed, data are limited. Accordingly, this section has made the assumptions below in order to arrive at the inventory figures presented in Table 6. Calculations and further elaboration can be found in Appendix A.

Other machine technologies are available that may require different energy and water inputs. Similarly, there are many variations of multiprocess wet cleaning. Energy, detergent, and water requirements will vary according to each method. Therefore, the figures in Table 6 represent only one wet cleaning scenario. Nevertheless, the inventory numbers are representative of a viable wet cleaning process. The input and output numbers calculated in Table 6 are performed using the following assumptions, which are based upon industry data:

Wet Cleaning Assumptions:

- the facility processes 79,958.2 pounds of clothes per year (a full explanation of this parameter is included in the Economic Analysis section);
- 70 percent of the garments are washed in the Aqua Clean washing machine, 30 percent are cleaned using the multiprocess wet cleaning method (the 70/30 split is discussed in the Background section at the beginning of the report);
- 100 percent of the garments are dried in the Aqua Clean dryer;[f]
- the wet cleaning machine used is a 50 lb. washing unit and a 30 lb. drying unit, based upon an Aqua Clean system;
- the Aqua Clean washing machine is operated at 55 percent of its 50 lb. capacity;
- one Aqua Clean Dryer load equals 27.5 lbs. of clothes;
- the washing machine processes 40 loads of clothes per five day work week;
- one wash load requires 30 minutes to process;
- the dryer processes 60 loads of clothes per five day work week; and
- one dryer load requires 11 minutes to process.

As mentioned in the Wet Machine Cleaning Description Section, certain garments may need to be drip dried. At this time, drip drying practices have not been well characterized. We assume that all garments are placed in the Aqua Clean dryer. Costs may increase if a larger facility is required to provide the space needed to hang garments while they dry, or if drip drying is a more labor intensive drying process. In addition, if the actual percentage is less than 100 percent, electricity costs would be expected to be lower, as would emissions resulting from that electricity use.

One reviewer commented that the actual percentage of garments dried on the wet machine dryer is likely to be lower than 100%, since some garments are not placed in the dryer for any length of time. For simplicity, we assume that all garments are placed on the dryer. If the actual number is less than 100%, electricty costs would be expected to lower, as well as emmissions from electricy use. However, cost may increase if a larger facility size is required to hang garments while they dry.

Detergent Requirements of the Wet Cleaning Process: Since wet cleaning uses water rather than a halogenated solvent to clean garments, a detergent is required for effective soil removal. Various detergents are available and an exact determination of amounts required will vary based upon each system. Environment Canada uses a pH neutral, phosphate-free detergent manufactured by Lever Chemical in their system.[33] At a quarter cup per load, 728 cups, or about 46 gallons, would be required per year in their wet cleaning system. Aqua Clean Systems markets a detergent called Aqua Safe that is also pH neutral and biodegradable. The Aqua Clean system would require approximately 135 gallons per year.

Energy Requirements of the Wet Cleaning Process: Electricity is required during the wet cleaning process to operate the wet cleaning machine and dryer, as well as during the multiprocess cleaning phase.

Wet Cleaning Washing Machine: To identify electricity requirements, electrical specifications for the Aqua Clean FLE220FC System 50 Washer are used.[34] Machine specs are 220 volts at 20 amps. Based upon conversations with an Aqua Clean representative, the washing machine is filled only to 50 percent to 60 percent of its capacity.[35] We have assumed that it is filled to 55 percent of its capacity, or 27.5 pounds. We have also assumed that only 70 percent of the garment load is washed by machine. Based upon these assumptions, computations yield 88 kilowatt hours(kWh)/wk of electricity usage. On a yearly basis, the electricity requirement for the washer is 4,576 kWh.

Wet Cleaning Dryer: To identify electricity requirements, electrical specifications for the Aqua Clean TT270RMC System 30 Dryer are used.[36] Machine specs are 220 volts at 15 amps. Although the dryer has a 30 pound capacity, we assume that 27.5 pounds of clothes are dried per load, based upon above reasoning. We also assume that 100 percent of the clothes processed by the facility are dried in the dryer. Based upon assumed activity level, computations yield 33.88 kWh/wk of electricity usage. On a yearly basis, the electricity requirement for the washer is 1,761.76 kWh.

A total of 6,338 kWh/yr. are required. The above data correspond well with evidence presented from an industry source using a different wet cleaning system in Germany. This source reported that wet cleaning machines have considerably lower energy requirements than comparable dry cleaning systems.[37] Although no measurements have yet been taken for confirmation, this result is to be expected because drying cycles are much shorter and no electricity-intensive device such as a refrigerated cooling unit is required.

As with the dry cleaning facility, additional energy is required in the form of natural gas to operate the boiler. The boiler heats the water used in the washing unit of the wet cleaning machine and the water used for the multiprocess wet cleaning portion of the garment stream. It is also used to produce the steam required. Use of natural gas is discussed at the end of this Inventory section.

Water Requirements of the Wet Cleaning Process: Water is required during t he wet cleaning process to wash the garments in the washing unit and also during the multiprocess cleaning phase.

Wet Cleaning Washing Machine: According to Aqua Clean manufacturers, the washing machine will use approximately 100 gallons of water per load. At 40 loads per week, the yearly water use would amount to 208,900 gallons per year.

Multiprocess cleaning: An additional 11,531 gallons of water are required for cleaning the remaining 30 percent of the clothes that are not machine washed, based upon EPA's Multiprocess wet study.[38] See the Appendix A for an explanation of this figure.

Air Emissions from the Wet Cleaning Process: No air emissions of concern are associated with the wet cleaning process.

Solid Waste Outputs of the Wet Cleaning Process: The amount of solid waste generated by the wet cleaning process is a fraction of that generated by dry cleaning. Lint collected in dryer filters is generated, as it is during dry cleaning. However, this waste product is not hazardous and is not expected to be significantly important.

Waterborne Wastes from the Wet Cleaning Process: The amount of water required for the wet cleaning system is significantly higher than that for dry cleaning. This water is discharged into the sewer system and requires wastewater treatment by a Publicly Owned Treatment Work (POTW). Thus, the concerns are the amount of suspended solids, phosphates, and ammonia in the water, as well as the additional amount of wastewater used by this system. Wet cleaning systems operating now primarily use phosphate free detergent. In addition, concerns have been raised regarding the spotting agents used. Although we have not addressed the amount of spotting agents used because we assume that they are generally the same for both dry and wet cleaning, they have been raised as an issue pertaining to wastewater associated with wet cleaning. This is because spotting agents are rinsed from the clothes during cleaning and discharged into the sewer system, whereas in dry cleaning, they are captured during the filtration process and disposed of with other solid waste products. This is an area where future research is needed in order to determine if there are any health or environmental impacts.

Other Energy Requirements

As mentioned above under the energy requirements sections of each process, additional energy is needed to operate the boiler, usually in the form of natural gas. In a dry cleaning facility, the boiler is used for many purposes, including heating the water used to steam and press garments, heating the water used to launder garments which are not dry cleaned, and heating the dry cleaning equipment such as the still cooker. In the wet cleaning facility, the boiler is also used for steaming and pressing, as well as for heating the water used by the washing unit. Extensive data on energy requirements of the boiler under each system have not been gathered. Due to the many uses of the boiler, it is difficult to isolate the portion of boiler use which goes solely toward either the dry cleaning process or the wet cleaning process we are comparing. At a dry cleaning facility, it is estimated that 20 percent of the steam generated by a typical boiler is used to provide steam to the dry cleaning machine.[39] No similar estimates have been made for a wet cleaning machine.

The amount required for wet cleaning also depends upon assumptions made about pressing and spotting times. Some sources have said that wet cleaning requires more pressing time but less spotting time than dry cleaning. More pressing time utilizes more steam, thus requiring more hot water, while less spotting time utilizes less hot water.[g] In addition, it is assumed that the dry cleaning facility requires a 20-horsepower boiler, while the wet cleaning facility requires a 10-horsepower boiler. (See Economics Section Appendices). Due to the uncertainty of natural gas consumption, we have not considered it in this inventory.

The above inventory data represent the input and output requirements of both a dry cleaning and wet cleaning process. These findings are useful as a basis of comparison of the two systems. This inventory data is used in the remainder of the report primarily to assess the comparative environmental impacts of each process. It is also used in the economic analysis to determine the economic viability of each process. These figures should also be used when weighing the health and regulatory considerations of each system.

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[g] One reviewer stated that spotting does not require water. This contradicts other sources which state that water is used in the spotting process in the form of steam from a steam gun.

[1]Source Reduction Research Partnership, Metropolitan Water District of Southern California and Environmental Defense Fund, *Source Reduction of Chlorinated Solvents - Dry Cleaning of Fabrics* (June 1988).
[2]U.S. EPA, *Proceedings International Roundtable on Pollution Prevention in the Drycleaning Industry* 1992.
[3]Ibid., p. 6.
[4]Source Reduction Research Partnership 1988.
[5]U.S. EPA, *Proceedings* 1992.
[6]Wolf 1995.
[7]U.S. EPA *Proceedings* 1992 p. 6.
[8]Elizabeth Hill, *Coming Clean: The Potential for Toxics Reduction in the Garment Care Industry*, (Los Angeles: University of California, 1995): 6–8.
[9]Ibid.
[10]Ibid.
[11]Source Reduction Research Partnership, 1988.
[12]U.S. EPA *Proceedings*, 1992.
[13]Source Reduction Research Partnership, 1988.
[14]Ibid.
[15]U.S. EPA *Proceedings*, 1992. p. 7.
[16]Source Reduction Research Partnership, 1988.
[17]U.S. EPA *Proceedings*, 1992. p. 7.
[18]DynaClean Solvent Distillation Systems, Fact Sheet discussing the DynaClean Solvent Distillation system (undated).
[19]U.S. EPA, *Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and an Alternative Process*, EPA 744-R-93-004 (1993): Appendix IV.
[20]Personal communication with Ohad Jehassi, Economist, U.S. EPA, January 30, 1995.
[21]U.S. EPA, *Multiprocess Wet Cleaning* 1993, Appendix IV.
[22]Ibid.
[23]Ibid.
[24]Ibid.
[25]Ibid.
[26]U.S. EPA, *Proceedings* 1992.
[27]Source Reduction Research Partnership 1988.
[28]Ibid.
[29]U.S. EPA, *Proceedings* 1992.
[30]U.S. EPA, *Multiprocess Wet Cleaning* 1993, Appendix IV.
[31]Ibid
[32]U.S. EPA, *Proceedings*, 1992, p. 10.
[33]Personal communication with Toby Brodkorb, Engineer, Environment Canada, December 12, 1994.
[34]Aqua Clean Systems, Inc., "Aqua Clean: The Environmentally Safe Alternative to Dry Cleaning," Fact Sheet, (undated).
[35]Personal communication with Kevin Daly, Product Manager, Aqua Clean Systems, Inc., January 3, 1995.
[36]Aqua Clean Systems, Inc., "Aqua Clean: The Environmentally Safe Alternative to Dry Cleaning," Fact Sheet (undated).
[37]Elizabeth Winter, "Wet Cleaning with the Miele-Kreussler Textile Cleaning System," Fact Sheet, (July 15, 1994).
[38]U.S. EPA, *Multiprocess Wet Cleaning* 1993, Appendix IV.
[39]U.S. EPA, *Multiprocess Wet Cleaning* 1993, Appendix IV.

FINDINGS

I. HUMAN HEALTH IMPACT ASSESSMENT

Over the last decade, it has become increasingly clear that at high exposure levels, perc poses a serious threat to human health. Damage to the central nervous system, early onset of liver and kidney damage, and temporary vision impairment are all well-documented after severe exposure. But currently, in a well-run dry cleaning facility that uses modern equipment, the risk of this type of acute exposure is uncommon. It is more difficult to answer questions about the minimum level at which chronic toxic effects occur, and the effects of long-term, low-level exposure such as that which dry cleaning employees are more likely to experience. Also exposed, although usually at significantly lower levels, are the general public who live above or next to a dry cleaning facility, who drink water contaminated with perc, and who bring freshly cleaned clothes containing residual perc into their homes.

Only recently has the scientific community begun to examine human health effects of perc at low as well as high levels. Data evaluating human health effects play a significant role in an evaluation of the overall impacts of the dry and wet cleaning systems. Health impacts also are used in developing regulations governing the use and disposal of perc. Currently, there is debate within the scientific community as to the correct classification of perc, a decision which effects how it is regulated. For example, the National Institute of Occupational Safety and Health (NIOSH) recommends perc be handled as if it were a "human carcinogen," the state of California classifies it as a "known carcinogen," and the International Agency for Research on Cancer (IARC) is revising its classification from Group 2B ("possibly carcinogenic to humans") to a Group 2A ("probably carcinogenic to humans").[1] However, the EPA has not yet officially classified perc. For the time being, it has unofficially adopted the U.S. EPA's Science Advisory Board's recommendation that perc be classified on a continuum between a "probable" and "possible" human carcinogen, and that steps be taken to reduce worker exposure. This section will explore the human health risks associated with dry and wet cleaning.

Health Effects of Perc

Numerous studies have shown significant, statistical health impacts associated with the use of perc. These studies document effects in human populations as well as laboratory animal populations. In terms of establishing guidelines for its use, data must be collected on the levels of exposure at which these effects occur, whether perc is carcinogenic in humans (a key factor in determining how it is regulated), and whether the pathways for human exposure exist. Systems such as the dry-to-dry closed-loop machine with a refrigerated condenser studied in this report are designed to control most perc emissions and significantly reduce the risk of human exposure.[h] However, it is important to consider health impacts associated with perc at a variety of different exposure levels since poor housekeeping practices and accidents can lead to high exposure even with sophisticated equipment. In addition, the type of machine studied in this report is as of 1991 used by only one-third of the industry,[2] and an analysis that only considers health risks associated with it would not accurately represent the current state of the industry.

Studies have linked perc with a host of health effects. Clinical studies, following short-term exposure of volunteers to a variety of concentrations of perc, ranging from 106 to 2,000 ppm (719 to 13,560 mg/m^3), observed symptoms ranging from mild eye and nasal irritation to dizziness and unconsciousness.[3,4] High levels of exposure can lead to "toxicity to the central nervous system which can result in coma, respiratory paralysis, or circulatory failure"[5] or even death.[6,7,8] With increased concentrations of perc, the severity of the effects increased, while the time until onset became shorter. However, even at current Occupational Safety and Health Administration (OSHA) permissible exposure levels (PELs) of 100 ppm, light-headedness, speech difficulties, nausea, and eye and throat irritation were observed in male and female volunteers exposed for seven hours/day for five consecutive days.[9,i]

Long-term exposure at levels below 40 ppm, well within the PELs, has been linked to subclinical neurobehavioral effects[10] such as psychological effects on personality, mood, and attention; and visual/spatial function, sensorimotor, intellectual, memory, and

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[h]The Amalgamated Clothing And Textile Workers Union (ACTWU) presented information to OSHA which indicated that perc exposure is reduced to 10.7 ppm for the operator of a unitary dry-to-dry machine as opposed to 58.4 ppm for the operator of a transfer-type machines. (29 CFR 1910.1000 Air Contaminants Proceedings from OSHA January 19, 1989, Section VII. Feasibility and Regulatory Analysis, Subsection F. Technological Feasibility; Feasibility Determination, SIC72--Personal Services.).

[i]Although the OSHA PEL is legally 100 ppm, OSHA had tried to establish in 1989 a PEL of 25 ppm, but following industry challenges to the method OSHA used to adopt the new PEL, it was remanded on procedural grounds. Recommended industry practice is to work within the 25 ppm level.

coordination functions.[11,12] Long-term occupational exposure has also been found to cause "clinical and preclinical effects upon frontal lobe and limbic functions [the frontal lobe 'affects a person's reliability, emotional stability, ability to reason, and ability to maintain self control,'[13] and limbic functions relate to vision]."

Research into potential effects on reproductive functioning has been conducted, but further research is needed. A study done by "Rachootin and Olsen (1983) reported an 'increased risk' of idiopathic ['of unknown causation'] infertility in females and exposure to dry cleaning chemicals."[14] "A Finnish study of pregnant dry cleaning workers found miscarriage rates three times higher than normal."[15] However, some studies have been unable to verify this increase in spontaneous abortion and congenital malformations among dry cleaning workers.[16] Further, the studies suffered from a lack of data concerning the type(s) of dry cleaning chemicals involved and the intensity of exposure to perc or other chemicals.

A study of the effects of perchloroethylene exposure on human semen quality found that sperm in dry cleaners were "significantly more likely to be round...and less likely to be narrow...than the sperm of laundry workers." In addition, "sperm of dry cleaners tended to swim with greater amplitude of lateral head displacement (ALH) [and less linearity] than those of laundry workers."[17] These effects were "dose-related to expired air levels" of perc. Round sperm are unable to penetrate the ova. ALH and linearity are measures of the pattern of sperm motion. "Changes in these parameters seem to reflect alterations in the functioning of the cell plasma membrane."[18] Although the study controlled for sociodemographic characteristics, relevant medical history, and exposure information, it did include workers in shops with both transfer and dry-to-dry machines. In addition, it was not able to isolate a cohort exposed only to perc. Many of the studies done on reproductive functioning "support the hypothesis that perchloroethylene affects the hormone system."[19] However, due to small sample sizes and other limitations, the findings are often not conclusive. They do however demonstrate that these effects cannot be ruled out and therefore "stress the need for further study."[20]

Standard Setting Criteria and Carcinogenic Characteristics of Perc

Determining the level of cancer risk from exposure to perc is a complex and highly debated issue. A number of studies have examined the effects of perc on animal and human populations, yet their findings have been subjected to varied interpretations within the scientific community. An August 1994 study sponsored by the National Institute for Occupational Safety and Health (NIOSH) and National Institute of Environmental Safety and Health updated, confirmed, and strengthened the findings of a 1987 NIOSH study by Brown and Kaplan. These updated findings were of "significant excess bladder cancer mortality and elevated digestive tract cancer mortality"[21] in dry cleaning workers who had worked "for at least 1 year before 1960 at a shop using perc as the primary solvent and who were not known to have been exposed to carbon tetrachloride."[22] In addition, the 1994 study found a significant excess of esophageal cancer deaths among perc-only workers with five or more years of employment and 20 or more years of latency.[23,j]

The 1994 study was important because it identified a subcohort of dry cleaning workers who had been exposed only to perc. As perc has only been the preferred solvent for the dry cleaning industry for approximately half a century,[24] previous studies of dry cleaning workers dealt with populations that had often been exposed to a variety of solvents, not just perc. Thus, it was difficult for those studies to state whether observed health effects were caused by exposure to perc. Although most of the population studied by the NIOSH researchers did include a large number of workers exposed to a variety of dry cleaning solvents, the researchers were able to identify a subcohort of workers who had only been exposed to perc.

A 1993 study conducted by the Massachusetts Department of Public Health and sponsored by Boston University examined populations served by water contaminated when perc leached into the drinking water from the "inner vinyl lining of certain asbestos cement water

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[j]Janet C. Hickman noted that "it was not clarified what role smoking had to do with these cancers" and "it was not clear in the NIOSH study if the subcohort was adequately controlled for life style patterns" (Janet C. Hickman, written comments on a draft, The Dow Chemical Co.'s TS&D, March 14, 1995). In their study, Ruder et al. addressed the concern that smoking is considered a risk factor for esophageal, pancreatic, and bladder cancers. Because smokers have a "fivefold higher risk of lung than of bladder cancer," one would expect, based on the number of bladder cancers observed a much higher than observed number of lung cancers. Therefore, they argue, "...a smoking adjustment could not account for the significantly elevated risks of bladder, esophageal, and pancreatic cancer in the group with longest latency and duration of employment."

Excess drinking is also a risk factor for esophageal cancer. However, since increased incidences of cirrhosis of the liver, which is also linked with excess drinking was not observed, Ruder et al. determined the excess esophageal cancer mortality was not due to drinking (Ruder et al. 1994, p. 873).

Adding to the debate, Dr. Noel Weiss, a cancer epidemiologist with the University of Washington's School of Public Health, conducted an analysis of the current research. His work was supported by the Halogenated Solvents Industry Alliance, a group supported by industry groups such as The Dow Chemical Co. In his article, which will be published in *Cancer Causes and Control,* Dr. Weiss argues that the esophageal cancer observed may be due to a combination of smoking and drinking at levels lower than those which would cause cirrhosis of the liver. Therefore, a lack of cirrhosis of the liver would not rule out the potential that perc is not the cause of the increases in esophageal cancer (Weiss 1995).

distribution pipes."[25] The researchers reported an increased risk of leukemia and bladder cancer.[26] For both leukemia and bladder cancer, the study found that the increased risk was related to the dose imbibed.[27] These findings suggest that the carcinogenic potential of perc "is a matter of significant public health concern."[28,29] In another case in the Alyeska Basin subdivision in Alaska, coal-tar enamel-coated steel pipes which are also used elsewhere in the U.S. "leached toxic chemicals into the drinking water." Analysis determined that the pipe lining contained up to 421 ppm of PCE.[30]

"Studies conducted in the U.S. and Sweden have [also] demonstrated that the incidence of liver and breast cancer are unusually high among dry cleaning workers."[31] Significant excesses were also seen for esophageal cancer, intestinal cancer, and kidney cancer.

The data from studies such as these and others contribute to the information used by the regulatory agencies in determining the relative cancer risk associated with the use of perc and the appropriate controls. However, each agency's system of analysis has its own strengths and weaknesses. The next sections show how government-set standards are limited in their ability to enforce the most protective perc levels for dry cleaners.

EPA/SAB Classification Schema

The EPA carcinogenicity classification system is based on the amount of animal and human data available.[32] Unfortunately, these classifications are often used in ways contrary to their design. For example the classifications are not intended to be interpreted as a risk assessment since a chemical's classification status does not take into consideration factors such as "the extent of potential exposures, [which] may be more important or equally important in determining risk management strategies ...."[33] In an August 1987 letter to the EPA Science Advisory Board, then-EPA Administrator Lee Thomas addressed this dilemma of classifications based solely on available studies being used to determine cancer risk, irrespective of compounding issues such as level and extent of exposure:

> ...A decision to regulate a compound represents a statement of potential hazard *in the absence of other factors such as exposure*. A regulatory decision by EPA on whether to control the sources of a specific compound, and the degree of control must necessarily weigh hazard, potency, exposure and other factors. It is clear, however, that EPA's classification of a compound has major ramifications beyond its use in EPA's own decision making process. Rightly or wrongly, state environmental decisions and public perceptions of risk are often triggered by an EPA determination to classify a compound as a B2 carcinogen [probable human carcinogen]. This black-white interpretation of the classification system is troubling."[34] (Emphasis added.)

The U.S. EPA Science Advisory Board (SAB) is an independent entity from the U.S. EPA. It was chartered by Congress to provide scientific advice. The Board is composed of non-federal scientists who are appointed by the U.S. EPA Administrator at the recommendation of the SAB staff. Scientists, drawn from a variety of fields including industry, are appointed for two year terms, although appointments are commonly renewed three or four times, for an average tenure of six to eight years. The SAB mostly reviews documents submitted by the U.S. EPA. According to Sam Rondberg of the SAB, the Board's findings are not controlled by the U.S. EPA and are often highly critical of the Agency. Although the EPA is under no obligation to act on the SAB's review, if the Agency is in the process of developing regulatory policy, questions are often raised during the public comment period if the Agency is "off at a tangent" from what the SAB recommended.[35] According to Rondberg, the U.S. EPA disregards the Board only with "considerable danger."

The SAB has classified perc on a continuum between a B2 (probable human carcinogen) and C (possible human carcinogen). Although, according to the SAB, a lack of interpretable epidemiological data prevents perc from being classified as a B2 compound, the evidence supporting a B2 classification *is stronger* than for most other compounds classified as possible human carcinogens (C). For a "C" classification, the evidence must merely "confirm that [the compound] should be considered as an animal carcinogen." In the case of perc, the SAB cites evidence showing "liver tumors in male and female mice, kidney tumors in male rats, and, possibly, mononuclear cell leukemia in male and female rats" as sufficient for meeting a "C" classification. Yet perc falls in an awkward gray zone in the classification system:

> As perchloroethylene illustrates, the distinction between the B2 and C categories can be an arbitrary distinction on a continuum of weight of evidence....From a scientific point of view, it seems inappropriate for EPA and other agencies to regulate substances that are classified B2 and not to consider regulations of compounds classified as C, regardless of the level of human exposure....A substance classified as C (limited evidence in animals) for which human exposure is high may represent a much greater threat to human health [than substances classified as B2, B1, or even A where exposure levels are low].
>
> EPA and other agencies (including those in state governments) may, therefore wish to take steps to reduce high exposures to substances in the C category whenever there appears to a potentially significant threat to human health (in the sense that the plausible upper bound estimate of potency times lifetime exposure is above the threshold where regulation may be judged appropriate). Indoor exposure to perchloroethylene, such as might be found in dry cleaning establishments not using the equivalent of good industrial hygiene practices, could merit action under this criterion....In many instances, this appearance of safety results from not yet having the results from well-designed bioassays such as those conducted by the National Toxicology Program.[36]

Thus, the SAB cautions that despite the current perc classification level of only a possible human carcinogen, due to the wide use of and exposure of workers to perc, it would be wise to reduce worker exposure to the compound.

The U.S. EPA has adopted the SAB recommendation for the classification of perc, that is, that perc is classified on a continuum between a B2 (probable carcinogen) and C (possible carcinogen).[37] However, to better classify compounds such as perc which fall into a gray area, the EPA is currently in the process of revising the system for classifying pollutants, moving away from the letter system to a more descriptive system.[38] The next section provides an overview of current indoor air quality standards for perc and identifies some of the strengths and weaknesses of the current standard-setting criteria.

Indoor Air Quality Standards

There are two types of limits controlling air exposures: Threshold Limit Values (TLVs) and Permissible Exposure Limits (PELs). "PELs are those employee exposure limits for toxic chemicals published by OSHA as legal standards. . . . The PELs used by OSHA are based on the TLVs." The TLVs were set by a private group in 1968, the American Conference of Governmental Industrial Hygienists (ACGIH), and in 1970 were adopted by OSHA as its PELs. Since then, revisions to the TLVs, based on the most recent and accurate scientific information, have almost always been lower than the original value.

OSHA was established to protect workers, but its ability to do this is limited by flaws in the structure of the system used for setting standards. According to the UMDNJ--Robert Wood Johnson Medical School Guidebook for Health and Safety in Small Industry, there are several problems associated with the way exposure limits are currently calculated:

- For many substances, the information available for choosing the exposure limit is very poor. Since we do not always have solid, reliable information, some guesswork is necessarily involved. Consequently, recommended exposure levels are often changed (and almost always to a lower level) when new information becomes available.

- For some substances, the recommended exposure limit is based only on preventing acute effects. Chronic effects are harder to study. Often, we simply don't have enough information about long-term exposure to know if the substance can cause serious chronic problems at low levels of exposure.

- The way a particular level of a chemical affects one person may be different from the way it affects another person. Some people may be more easily affected than others. So even if the exposure limit protects most people, it may not protect people who are extremely sensitive or more susceptible to a substance.

- TLVs regulate single substances. *They do not consider what happens when several chemicals combine to produce effects far more harmful than any one substance produces by itself ('synergistic' effects).* Nor do TLVs fully consider what happens when substances are changed in the body to more harmful materials.[39] (Emphasis added.)

These factors suggest that there are serious constraints on OSHA's ability to truly determine a compound's health impacts. Given this climate of uncertainty, the authors of the guidebook suggest that exposure levels should always be kept at the lowest level, whether that be the TLV or PEL.

In 1989, in an attempt to reevaluate the PEL for perc, OSHA set new standards lowering the PEL for perc from 100 ppm to 25 ppm. After reviewing the available health data, OSHA had concluded that "perchloroethylene is a potential human carcinogen that presents a significant risk of material health impairment to workers exposed to it in their places of work."[40] This action was part of an OSHA review of 428 substances. Immediately after OSHA passed the new PELs, industry challenged OSHA's ability to revise the PELs of such a large group of compounds. As a result of the challenge, in July 1992 an appeals court overturned the PELs and they reverted back to their former level, in the case of perc, 100 ppm. For more information on how the TLVs and PELs are established and about the court decision, see Appendix B. The next section examines the strengths and weaknesses with the current process for establishing water quality standards.

Drinking Water Quality Standards[41]

The starting point for the Agency's analysis of appropriate water quality standards is usually the U.S. EPA's cancer classification of a compound (i.e., A, B, C, D, or E). General guidelines dictate that Group A, B1, and B2 contaminants are placed in Category I, Group C contaminants are placed in Category II, and Group D and E fall into Category III. However, where there is evidence of additional risk from ingestion taking into consideration factors such as the weight of evidence of carcinogenicity in humans using bioassays in animals and human epidemiological studies, pharmacokinetics and exposure, the contaminant may be placed in a different category. In the case of perc, a volatile organic compound, although the Agency had not yet determined a classification for perc by January 1991, Congress had directed the Agency to take a final action on a maximum contaminant level goal (MCLG) of perc as well as 82 other chemicals.

The crux of the decision for the Agency rested with its categorization of perc as a probable or possible human carcinogen for purposes of setting an MCLG under the Safe Drinking Water Act (SDWA). The Agency decided to categorize perc as a Category I contaminant for drinking water regulation. Category I chemicals are those where the Agency feels there is "strong evidence of carcinogenicity." Since perc is a volatile organic compound and was classified as a Category I contaminant, as a matter of policy, the MCLG was set at zero. The Agency based its decision "on the available carcinogenicity evidence from experimental animal studies and the high frequency of occurrence in drinking water.... [usually due to] improper waste disposal." The Agency also set the maximum contaminant level (MCL) at 0.005 ppm "to reduce the risk of cancer or other adverse health effects which have been observed in laboratory animals."

The Debate

As with much scientific data, there is debate over how to interpret the data used to classify and regulate perc. Although the SAB feels the weight of evidence of carcinogenicity in humans is not sufficient to classify perc as a probable human carcinogen, other groups disagree. Since 1977 with the release of the National Cancer Institute's bioassay results showing an excess of hepatocellular carcinomas in male and female mice, NIOSH has recommended that "perchloroethylene be handled as if it is a human carcinogen, minimizing exposure to the lowest level possible."[42] In California, perc is classified as a known carcinogen.[43] In 1987, the International Agency for Research on Cancer (IARC) classified perc as a category 2B carcinogen (i.e., a substance for which the evidence in animals is sufficient).[44,k] The New York Department of Public Health set a maximum indoor air concentration of perc at 15 parts per billion (ppb) in homes.[45]

The Need for Further Study

Additional analysis of the health impacts of perc is especially important in terms of setting safe usage standards. During the 1989 OSHA hearings, OSHA disagreed with the Halogenated Solvent Industry Alliance's (HSIA) arguments point-by-point and concluded that perc is a probable human carcinogen (category 2B) whereas the HSIA argued that perc should remain classified as only a possible human carcinogen (category C). For a full review of the arguments presented by OSHA and HSIA, see Appendix B.

[k]The IARC is currently revising its cancer classification from a Group 2B (possibly carcinogenic) to a Group 2A (probably carcinogenic to humans).

Further studies would clarify the linkages between perc and various cancers. The SAB identified four specific areas that warrant further research:

- continued risk assessment on perc,
- focus on findings and how they relate to dose-response,
- use of appropriate alternative dose-response models in addition to the U.S. EPA's multistage model to assess its strengths and weaknesses in analyzing human cancer risk, and
- developing interpretable epidemiological data.

Even though perc has been shown to have negative health impacts on humans, the risk is reduced if humans do not come in contact with the compound. The next section explores the possible avenues for human exposure to perc.

Exposure Pathways

Recent studies have identified a number of exposure pathways affecting both dry cleaning workers and others, not employed by the industry.[46,47,48,49] Employees of dry cleaners are exposed to perc vapors in the shop air, which is measured both by quantifying the amount of perc in the air and by quantifying the amount in employees' exhalations, and through dermal contact. The public can be exposed through contaminated drinking water supplies, absorption of perc by food products, absorption by building materials and movement of vapors into apartments above and adjacent to dry cleaners, off-gassing from dry cleaned clothes, and bioconcentration in plants and animals.[1] Large populations of exposed individuals have been extensively studied, and the findings of these studies will be described below.

Dry Cleaning Workers: Inhalation and Skin Contact

The main route for human exposure to perc is by inhalation, although absorption through the mouth and by skin contact is also important.[50] Within a dry cleaning shop using dry-to-dry closed-loop machines with a refrigerated condenser, fugitive emissions can be released from a number of sources:

- Opening of the machine door, especially when the fan that controls emissions is malfunctioning,

[1]There is low to moderate potential for bioconcentration of perc based on studies of fish and plants. (Canadian Environmental Protection Act 1993, p. 7.)

- Storage of perc and spent filters,
- Leaking equipment,
- Poorly maintained equipment,
- Vaporization of wastewater,
- Improperly dried clothes,
- Regular maintenance and cleaning of stills,
- Spotting boards, and
- During filter replacement.[51]

In addition, facilities not using dry-to-dry closed-loop machines with refrigerated condensers, or those facilities with poor housekeeping practices risk additional exposure from the following sources:

- **Garment transfer.** Although only transfer-type machines require manual transfer of the garments from the washer to the dryer, some operators of closed-loop dry-to-dry machines bypass the closed-loop feature of the machines and manually transfer the cleaned clothes into separate dryers in order to increase the volume of clothes the machine can process.[52,m] This practice is not considered a correct usage of the closed-loop dry-to-dry machine, and causes perc emissions.

- **Transferring new perc into the cleaning machine.** With the newest technology available, perc is transferred from specially designed 20-gallon solvent containers which hook on to the dry cleaning machine and the solvent is transferred by means of a pump. All the connections in this system are sealed, so that the employee is not exposed to perc during the process. However, according to Elden Dickinson of the Michigan Department of Public Health, this system is still in its infancy and has not yet been adopted by many shops. Another method of transferring the solvent involves

[m] "Many newer machines include a door lock, preventing the door from being opened until the dry cycle is complete" (Hickman 1995). The door lock would prevent dry cleaners from misusing the machine and opening the door before the end of the cycle, inadvertently exposing themselves to perc emissions. According to Ernest Hickle, Director of Engineering at Forenta, a dry cleaning equipment manufacturer, machinery innovations have occurred, particularly in the last two years, driven largely by EPA and OSHA. Forenta introduced, in the past six to 12 months, its new Carbon Vapor Adsorber (CVA) Model. The CVA pulls fresh air into the wheel, pulls the air out of the wheel and through a carbon bed to capture the perc, and then releases the air to the atmosphere. When the door lock releases, approximately 45 seconds after the machine cycle ends, there is a significantly lower level of perc to which the operator is exposed. Although the carbon bed feature is only available from Forenta on its CVA model, Forenta's dry-to-dry machines in general include a delayed opening so that the door stays locked for 45 seconds after the machine cycle ends. This allows the wheel to coast to a complete stop. (Personal communication with Ernest Hickle, Director of Engineering at Forenta, March 30, 1995.)

using a handheld hose to pump solvent into an opening on the cleaning machine, permitting vapors to escape. Still others which have bulk storage of perc transfer the chemical in open buckets and manually pour the solvent into the machine.[53]

- **Inadequate ventilation.** Dry cleaners are required to provide adequate ventilation, however shops with poor housekeeping practices may postpone repairing broken fans. This lack of proper ventilation can significantly increase the degree of perc exposure.[54]

Other potential sources of contamination result from spills, leakage, and boil-over of a cooker or still.[55] For example, in October 1994, a truck delivering supplies to a new dry cleaning shop in a Michigan shopping mall ruptured a perc line under the trailer. Over 200 gallons of solvent spilled. Although the cleanup was handled quickly and efficiently, the area had to be evacuated for an hour, and much of the solvent was absorbed by the parking lot pavement and the ground exposed by cracks in the pavement which then necessitated that it be removed and replaced.[56] Although accidents such as this one are unusual, it is one of the many ways humans can be exposed to perc in levels exceeding the guidelines.

To demonstrate the difficulty a cleaner has controlling perc emissions in the workplace, it is useful to consider the results of an August 8, 1994 planned inspection of the Neighborhood Cleaners Association (NCA) dry cleaning training workshop by the New York Advocate's Office. The NCA facility has two closed-loop, dry-to-dry machines with refrigerated condensers. Readings of the ambient air quality revealed perc levels ranging from 10–44 ppm. Specific leaks were occurring from a malfunctioning carbon adsorber that was emitting perc at a level of 100 ppm. A storage barrel of perc with a loose nozzle was releasing levels as high as 2,000 ppm. A broken door fan caused readings of 500–700 ppm at one of the machine's doors and readings of 80 ppm were taken around a worn seal around a lint cleaning device.[57] These findings are supported by numerous studies of field inspections which reveal that malfunctioning equipment and higher than expected levels of perc emissions are common in dry cleaners.[58]

Studies have found that "average environmental concentration is a relatively accurate estimator of dose actually delivered to body tissues overall."[59,60] Thus, indoor air readings are a relatively accurate gauge of the amount of perc absorbed by body tissue. Further, "inhalation is considered to be the most important route of exposure."[61] In a 1990 study, "the majority of operators' air samples exceeded 25 ppm, [one quarter of the existing PEL of 100 ppm and higher than the industry recommendation of a 25 ppm PEL set by ACGIH]. On average, operators experienced over three times the air concentrations and twice the breath levels of other employees, with statistical significance attained."[62] Contaminated shop air is a key means by which workers are exposed to the harmful effects of perc, in levels exceeding currently accepted standards.

Studies have also shown that families of dry cleaning workers are "exposed to higher levels of ambient PCE than is the general population" because the workers bring the perc into their homes by way of exhalations from their lungs and emissions from their clothing.[n] Homes of dry cleaners had perc levels ranging from 0.025–9.6 mg/m^3 compared to control households with 0.001–0.056 mg/m^3.[63] The general public is also exposed when an individual visits a dry cleaning facility to drop off or pick up clean clothing. Measures of breath exhalations following a visit to a dry cleaner have shown elevated levels of perc.[64] Although skin contact is less frequent, workers can also suffer burns, blisters, and erythema [redness of the skin produced by congestion of the capillaries[65]] if prolonged contact occurs. Chronic exposure can lead to dry and scaly forearms and hands that are then more susceptible to infection.[66] Another exposure pathway is through ambient air levels in residences that are above or next door to dry cleaners.

Ambient Air Levels in Residences

The public is also at risk of exposure. Perc can permeate buildings and apartments in the vicinity of a dry cleaner. In New York City, "state health inspectors had tested the air in 7 apartments located above dry cleaners and discovered perc levels an average of 150 times the local guideline of 0.4 ppm."[67] Even modern machines that combine cleaning and drying in one unit, can be the source of contamination if operated incorrectly. One apartment above a newer machine was found to have perc fumes 1,000 times the safe level.[68]

Off-gassing

In addition to direct emissions from dry cleaners, individuals inadvertently increase their exposure through the perc retained in dry cleaned clothes that they bring home. The process by which the perc evaporates from the clothes is know as off-gassing. Particularly problematic materials are acetate and nylon, "which are highly hydrophobic" and can hold higher amounts of residual TCE, a perc by-product, than other fibers.[69] Exposure can be quite high. For example, one study examined perc air concentrations in cars in which 15.4 lbs. (7 kg) clothes

[n]This latter type of emission is known as off-gassing and will be discussed in more detail below (Aggazzotti, 1994 p. 492).

dry-cleaned in a coin-operated facility were deposited. After 15 minutes, the ambient level of perc in the car was up to 350 ppm.[70] It is important to note however, that clothes cleaned in coin-ops often have higher emissions as they are operated by consumers, not professional cleaners, and therefore are more prone to poor operating practices. Also, acetate and nylon do not make up the majority of the professional cleaning stream.

Another study, which did not specify the type of dry cleaning machine used, found "elevated indoor air levels and human exposures to tetrachloroethylene ... at seven of the nine homes with dry cleaned clothes. Indoor air concentrations reached 300 g/m^3 in one home and elevated indoor levels persisted for at least 48 hrs in all seven homes."[71] In addition, "breath levels of tetrachloroethylene increased two to six-fold for participants living in seven homes with increased air levels."[72] Increases in indoor air and breath levels were significantly related to the number of garments divided by the home volume.[73]

The study also found that breath levels remained high even after air levels had fallen. The authors postulated that this effect "may reflect the accumulation in the body with prolonged exposure and the relatively long elimination half-life for tetrachloroethylene....As exposure concentrations dropped the accumulated chemical would continue to be released to the bloodstream and would appear in the exhaled breath."[74] Thus far, there is no comparable data for emissions from closed-loop, dry-to-dry machines with refrigerated condensers. Preliminary data suggest that it would be lower.

Aside from improvements in the machinery and process used to clean the clothes, there is little that can be done to reduce the residual levels on the clothes once they leave the shop. Airing out dry cleaned clothes for short periods of time (4 to 8 hours) is not effective at reducing emissions and further, the emissions levels may be exacerbated by being absorbed by materials in the homes which can release the fumes over an extended period of time.[75,76] Storing garments in plastic bags would reduce the air flow and may "reduce the magnitude of short-term exposures but increase the total duration of the exposure."[77] Increasing air flow within the house, not wearing freshly cleaned clothes, and bringing only a few cleaned garments into the home at one time, may be the best ways for the general public to control its exposure to residual perc on clothing once the clothes leave the dry cleaner.[78]

Ingestion: Food and Water

Individuals are also exposed to perc through the foods and liquids they ingest. Perc accumulates readily in fatty foods. A British Broadcasting Corporation study found perc concentrations of almost twice the "safe" limit in butter in grocery stores near dry cleaners. Perc was also found in other fats and dairy products in restaurants near dry cleaners.[79,80,o] Perc is transmitted to breast milk and it is not known whether this may cause damage to infants of exposed nursing mothers.[81]

Drinking water has also proven to be a source of human exposure. Perc has entered the water supply through two primary means: groundwater contamination from dry cleaning establishments,[82] and vinyl liners used on the inside of the water pipes.[83] One method of groundwater contamination is through the perc-contaminated wastewater that is routinely (and in most states legally) poured down sewer systems.[84] Since sewer pipes are often designed to leak and perc is able to permeate concrete,[85] some groundwater contamination has occurred in this way. In some EPA surveys, 14 to 26 percent of groundwater and 38 percent of surface water sources have some degree of perc contamination, a matter of "significant public health concern."[86] In the town of New Minas, samples from both the deep and shallow wells serving the town were contaminated from a dry cleaning establishment.[87] Between 1986 and 1988, perc was detected in 14 of 23 samples of drinking water obtained in Prince Edward Island. The maximum reported concentration was 4.2 μg/L, which was well above the minimum quantitation limit of 0.5 μg/L.[88]

Health Effects of Wet Cleaning

The wet cleaning process has been used in professional cleaning facilities for a relatively short period of time. Thus far, no studies have evaluated health effects of this system. In the absence of formal studies, a general comparison of the two systems shows that the primary difference between wet and dry cleaning is the cleaning agent: nontoxic soap and water versus a toxic solvent, respectively. This difference will significantly reduce the potential health risks associated with wet cleaning.

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[o] In England in 1993, the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment of the Ministry of Agriculture Fisheries and Food evaluated the health risks from residual perc in food products. The committee concluded that although contamination of this type is "undesirable," the levels of uptake of tetrachloroethylene by butter and lard "do not give rise to concern with regard to adverse health effects."

In preliminary health analyses of wet cleaning, the primary concern that has been raised is the exposure of wet cleaning operators to solvents during the spotting process. However, since some wet cleaners have found nontoxic solutions to substitute for the spotting solvents and other wet cleaners continue to use the solvents used in dry cleaning, human exposure due to spotting solvents can be considered a constant for both the wet and dry cleaning systems for this comparative analysis and will not be studied separately.

Another concern is that the detergents used in wet cleaning are flushed with the wastewater down the sewer and ultimately processed by a publicly-owned treatment works (POTW). At this time, there is no evidence that either the cleaning agents or the soils washed from the clothing will pose a health risk.

As more wet cleaners come into operation, there will be an opportunity to assess other areas with potential health impacts and subject the system to the type of scientific analysis already underway on traditional dry cleaning. However at this point, the U.S. EPA and others studying the two systems anticipate that wet cleaning will have comparatively fewer human health effects than existing dry cleaning, since it does not use toxic solvents.

Final Remarks

Numerous advances in machine and emission control technology allow those dry cleaners using the type of machine considered in this report and employing good housekeeping practices to lower the level of perc exposure in their facilities. However, as of 1991, only one-third of dry cleaners use the closed-loop, dry-to-dry machine with a refrigerated condenser. Despite new federal regulations requiring dry cleaners to adopt this technology by 1996, some are exempted from compliance. For example, small cleaners using less than 140 gallons of perc a year whose equipment was installed prior to December 1991 do not have to upgrade under the new regulations.

Many of the studies discussed in the health section examine the dry cleaning industry as a whole, therefore including shops not using a closed-loop dry-to-dry machine with a refrigerated condenser. It is anticipated that the current regulations will significantly reduce exposure and health impacts. However, enough evidence exists linking perc with cancers, reproductive health effects, and subclinical neurobehavioral effects, that this linkage cannot be ruled out. More studies need to be done examining these illnesses and exploring whether health effects occur at low levels for different exposure periods. Also, the potential for exposure to higher levels will always be present during the production, transport, and transfer of perc through spills and other accidents or merely poor housekeeping practices. Therefore, although it is important to recognize the significant strides made in recent years by the dry cleaning industry, it would be unwise to fail to consider impacts from exposures above the current PEL when assessing the potential human health impacts from perc-dry cleaning. As this health section notes, despite the regulations, numerous shops are found to violate the standards.

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II. ENVIRONMENTAL IMPACT ASSESSMENT

An impact assessment is a quantitative and/or qualitative process to characterize and assess the effects of the environmental burdens identified in the Inventory Analysis.[1] An assessment addresses ecological, human health, and resource depletion effects. Examples are habitat alteration, resource extraction, and health consequences derived from atmospheric and waterborne emissions, and solid waste. Additional social welfare impacts can also be included. Although the assessment may quantify specific impacts, the primary goal is to establish a linkage between the products or processes and the potential impacts, and to characterize those impacts. The human health impacts of garment cleaning were discussed in the previous section.

There are many different methods and techniques available for conducting an impact assessment. A thorough, comprehensive impact assessment would examine the entire life cycle of each garment cleaning system, including raw materials extraction, manufacture, use, and disposal. The boundaries of this impact assessment are much narrower, quantitatively covering only the use stages for each cleaning process. More specifically, this study focuses on the process of cleaning fine washables and the associated inputs and outputs of the two garment cleaning systems that are identified in the inventory. It analyzes the use and disposal of cleaning products, but not the raw materials manufacture or processing. The impact assessment links inputs and outputs to their associated environmental burdens. The assessment does not assign an environmental score to a system or rate one system as environmentally superior to another.

Impacts From Perc Use

Most of the environmental impacts associated with the dry cleaning process are due to the use of perc. Perc impacts accrue during perc manufacturing, transportation, use, and disposal. There are no known natural sources of perc.[2] Therefore, all amounts found in the environment result from anthropogenic sources. The 119,100 metric tons of perc consumed annually in the commercial sector (see Inventory) are either lost to the atmosphere, become hazardous waste, or remain in the garment. In addition, a small amount of perc can remain in process water and enter the sewer system. A description of perc's environmental impacts follows.

Perc is part of a class of chlorine-based chemicals called organochlorines, in which chlorine is bonded to an organic compound. It is a member of the chlorinated solvents family. The Chemical Abstracts Service (CAS) registry number for perc (the unique identifier) is 127-18-4. It is generally listed as tetrachloroethylene. Perchloroethylene and perc are common synonyms. Table 7 summarizes the chemical and physical properties of perc. A comprehensive data set can be found in *Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume II* (Philip Howard, 1990), and *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals* (Donald Mackay, Wan Ying Shui, Kuo Ching Ma, 1993).

TABLE 7 - CHEMICAL AND PHYSICAL PROPERTIES OF PERCHLOROETHYLENE[3]

Boiling Point	121.0 degrees C at 760 mm Hg
Melting Point	-19.0 degrees C
Molecular Weight	165.82
Specific Gravity	1.6226
Odor Threshold	approximately 50 ppm
Log Octanol/Water Partition Coefficient	3.40
Water Solubility	150.30 mg/L at 25 degrees C
Vapor Pressure	18.49 mm Hg at 25 degrees C
Henry's Law Constant	1.49 x 10^{-2} atm-m^3/mole

The above characteristics are considered key properties when discussing chemical and physical characteristics of a chemical. An explanation of some of the properties follows.

The *Log Octanol/Water Partition Coefficient* is the equilibrium concentration ratio of the chemical in octanol, which is an organic liquid, to the concentration in water. This value is often used in regression equations with other properties to predict a chemical's soil adsorption, biological uptake, lipophilic storage (storage in fat cells), and biomagnification. The partition coefficient of perc, when correlated with other properties, is not significantly high, indicating that the potential of perc to bioaccumulate and/or adsorb to soils is moderate to low. For example, compared to certain types of DDT, the potential for perc to bioaccumulate is three to four orders of magnitude lower.[4]

Water Solubility provides insight into the fate and transport of a chemical in the environment. Chemicals with high water solubility are less likely to volatize from water, and tend to remain dissolved in the water column, to not partition to soil, and to not bioconcentrate. They are more likely to biodegrade. Chemicals with low water solubility are just the opposite; they tend to partition to sediment, bioconcentrate, volatize readily from water, and are less likely to biodegrade. Perc's water solubility value of 150.30 mg/L at 25 degrees Celsius is moderate, indicating that perc is fairly mobile in the environment.

Vapor pressure lends insight into the transport of a chemical in the environment. Volatility of a chemical is dependent upon vapor pressure in air, and upon both vapor pressure and water solubility when in water. Vapor pressure can also be viewed as a chemical's "solubility in air." Perc's vapor pressure of 18.49 mm Hg at 25 degrees Celsius indicates that perc will tend to volatize readily, which is a concern for indoor air quality.

Henry's Law Constant is the air/water partition coefficient. It provides an indication of the partition between air and water at equilibrium and is also used to calculate the rate of evaporation from water.

In addition, *Biodegradation* is an important chemical characteristic. The following biodegradation data pertaining to perc are taken from Howard's book.[5] Microbial degradation did not contribute to the removal of perc in a mesocosm experiment which simulated Narragansett Bay, Rhode Island. Under aerobic conditions there is no degradation of perc in 25 weeks in a batch experiment with a sewage innoculum or when low concentrations of perc (16 μg/L) were circulated through an acclimated aerobic biofilm column over a one year period. There is evidence that slow biodegradation of perc occurs under anaerobic conditions when the microorganisms have been acclimated, yielding trichloroethylene (TCE) as a product. A large reduction of perc which had been recirculated through a soil column for 14 days was attributed to adsorption and volatilization.

To sum up the above properties, perc has a high vapor pressure and Henry's Law constant. It has medium to high mobility in soil and is moderately soluble in water. This means that perc partitions primarily to air but can still migrate through soil to groundwater. Perc's residence time in the atmosphere ranges from one hour to approximately two months. In surface environments it is expected to be only a few days, but data indicate that perc will persist in groundwater for several months.[6]

Impacts from Perc Manufacturing

In order to provide a broader examination of the impacts from perc use, the manufacturing of perc could be comprehensively analyzed. At this point, we have not included quantitative perc manufacturing data because we have defined the boundaries of our system narrowly. Eliminating the manufacture and processing of perc understates the full environmental impacts, risks, and associated regulatory issues of perc use. Following is a brief qualitative discussion of perc use.

Perc is manufactured as a means of disposing of "junk" chlorinated hydrocarbons of one to three chlorine atoms.[7] Perc manufacturing involves petrochemical synthesis, thus having associated oil refining and petroleum consumption impacts. Increased risk results from accidental chlorine releases associated with use and transport of chlorine and worker exposure in petrochemical plants. Furthermore, chlorine gas is used both directly and indirectly in the production of perc.[8] According to U.S. EPA's database on acutely hazardous release events, 750 accidents involving chlorine gas occurred between 1980 to 1987, with 89 requiring evacuation. The database identifies chlorine gas as the chemical with the highest frequency of acutely hazardous release events.[9]

The chemicals hexachlorobenzene and hexachlorobutadiene are produced as by-products of the manufacturing process of perc.[10] Both chemicals are classified as hazardous. Hexachlorobenzene is among the most persistent environmental pollutants, and it bioaccumulates in the environment, in animals, and in humans.[11] The half life of hexachlorobenzene in soil is 3 to 6 years, and in groundwater it is 30 to 300 days.[12] There is evidence that hexachlorobenzene is toxic to young children, and the chemical has been found to decrease the survival rates of young children. Studies of animal exposure to hexachlorobenzene show harm to the liver, immune system, kidneys, and blood, as well as cancer of the liver and thyroid.[13] It is estimated that 7,700 to 25,300 pounds of hexachlorobenzene were produced as a by-product in the manufacture of chlorinated solvents, including perc, in 1984.[14] There are no commercial uses for hexachlorobenzene. It must be disposed of as a hazardous waste, and is usually incinerated.

Information about the fate and transport of hexachlorobutadiene is not as well known as that for hexachlorobenzene, but the chemical also poses health and environmental risks. U.S. EPA classifies hexachlorobutadiene as a possible human carcinogen.[15] Animal studies of exposure to the chemical have shown brain, kidney, and liver damage, as well as a decrease in fetal body weights.[16] U.S. EPA reports that about 28 million pounds of hexachlorobutadiene were produced as a by-product of chlorinated solvent manufacture in 1982.[17] The methods of disposal for 1982 production included incineration (68 percent), deep well injection (32 percent), and hazardous waste landfilling (less than 0.2 percent).[18]

Information about the manufacture of perc is important to consider in a comprehensive analysis because it fully addresses the life cycle of perc and all its impacts. The above data provide only a partial representation, but show that impacts occur not only during the use of perc in the garment cleaning process and the subsequent disposal, but also throughout all aspects of the life cycle of perc.

Atmospheric Emissions of Perc

The majority of perc losses occur into the atmosphere, where it exists in vapor phase. In addition to direct venting, perc enters the atmosphere by seepage through floors, ceilings, open windows, and walls. Once in vapor phase, the primary mechanism of perc breakdown is through chemical reaction with photochemically-produced hydroxyl radicals or chlorine atoms produced by photooxidation.[19] Estimated photooxidation time scales range from an approximate half-life of two months[20] to complete degradation in one hour.[21] By-products of breakdown in the atmosphere are phosgene, trichloroacetyl chloride, trichloroacetic acid, carbon monoxide, and hydrochloric acid.[22] Vinyl chloride and carbon tetrachloride can also be produced.[23] In addition, thermal degradation of perc poses potential hazards, resulting in hydrogen chloride, carbon dioxide, carbon monoxide, and chlorine, which can be extremely toxic.[24]

Vinyl chloride is a known human carcinogen,[25] and phosgene is highly toxic.[26] Carbon tetrachloride contributes to stratospheric ozone depletion. One study estimated that as much as 8 percent of atmospheric perc, measured by weight, could eventually be converted into carbon tetrachloride.[27] While this study implicates perc as a stratospheric ozone depleter, other sources indicate otherwise. The Canadian government states that due to the low concentration of perc in the atmosphere and perc's short half-life, perc does not contribute significantly to depletion of stratospheric ozone.[28] The U.S. government has concluded that reaction of perc with atmospheric ozone is too slow to be environmentally important.[29] Trichloroacetic acid is a known herbicide. Studies have indicated that fir and Norway spruce trees in Germany and Finland have shown an increased incidence of chlorosis (bleaching of needles), necrosis (death of needles) and premature needle loss over the last two decades.[30] These effects are linked in part to this by-product of perc degradation.[31]

Perc is also a significant contributor to indoor air pollution. Once in the ambient air, perc may be drawn into other buildings through ventilation or air conditioning systems. Residents of homes located adjacent to or near a dry cleaning facility are at risk of perc exposure for potentially longer periods of time than dry cleaning workers. This is particularly true for those residents who spend most of their time at home, such as the elderly, young children, and the homebound. Perc emissions also result from dry cleaned garments. This process is called off-gassing and can result in elevated levels of perc in a residence when clothes are brought back home. Off-gassing is discussed in the Human Health section of this study.

In situations where dry cleaners are located close or adjacent to grocery stores, emissions pose the problem of food contamination. Perc is lipophilic, meaning it is absorbed by fatty cells and tissues. Therefore, certain foods, particularly fatty foods such as butter, can become contaminated with perc. In a study of butters collected from 14 retail outlets in Washington D.C., researchers found elevated levels of perc in samples taken from stores near dry cleaning facilities.[32] However, another study conducted by England's Ministry of Agriculture Fisheries and Food, Committee on Toxicity concluded that the level of perc uptake in foods such as butter and lard was not high enough to cause adverse human health concerns.[33] Perc uptake in food can also result when food items come in close proximity to recently dry cleaned garments. Tests have shown perc uptake to occur in less than one hour in grocery items placed in a closed car with recently dry cleaned garments.[34]

Perc Impacts on Surface Water

Perc has been detected in rain, and can enter open surface water systems by atmospheric rain washout,[35] as do many of the breakdown components of perc. Deposition by this method can occur directly into the water body or enter as runoff. Perc also enters surface water through discharge of separator water from a dry cleaning machine and by spills. Once in water, perc, which has a higher density than water, sinks to the bottom surface where it can coalesce in droplets. In the case of a concentrated spill into water, a large portion of perc will coalesce to form dense puddles on the bottom. Subsequently, small drops will separate to resuspend in the water column and volatize.[36]

Due to perc's high vapor pressure, most perc which enters an open water system evaporates fairly quickly. The half-life for evaporation from water is dependent upon wind and mixing conditions and estimated range is from three hours to fourteen days in rivers, lakes, and ponds.[37] One study showed that in a sea water aquarium, evaporation of perc resulted in a half life of eight days.[38] Another study of a natural pond resulted in disappearance of perc in five days at a dose level of 25 ppm and 36 days at a level of 250 ppm.[39] As a result, high concentrations of perc in water are not common. Perc has a low to moderate potential for bioconcentration in aquatic organisms based upon its log octanol/water partition coefficient,[40,41] and is not expected to significantly adsorb to sediment.

Wastewater treatment plants generally do not treat specifically for perc. Therefore, perc which enters wastewater systems is removed only through vaporization, and has the potential to remain in the system. In a wastewater treatment system, sewer water first undergoes primary treatment, in which pools of water sit outside in order to allow for suspended solids to settle. During this phase, any perc which may be in the wastewater partially volatizes into the atmosphere, leaving behind minute amounts. Most treatment plants do not have to treat wastewater for perc.[42] Extended aeration is needed to allow perc to discharge into the air. Releases of perc from wastewater treatment plants in Sarnia, Ontario and Peace River, Alberta, have been reported. The influent level at the Sarnia plant was 31 micrograms per liter, and effluent contained 26 micrograms per liter of perc.[43]

Perc Impacts on Groundwater

Perc can enter groundwater directly through soil migration from contact with the ground, which may occur during a spill or leakage from disposal. Additionally, perc which enters the sewer system from discharge of separator water or deliberate disposal can escape through leaks which may exist in the system and also by migration through concrete sewer pipes. Past disposal into septic systems has also contaminated groundwater, although this practice is now illegal.

Perc absorption into soils depends upon characteristics of the soil and the amount of perc released. Perc passes through sandy soils at almost the same rate as water, while soils having a higher organic carbon content and clay content tend to have a higher retention level of perc. Volatilization of perc from dry soil should be fairly rapid. Nevertheless, perc is expected to be mobile in many soils and, therefore, able to penetrate to depths where groundwater can be contaminated.[44] In a bank infiltration system in Switzerland and the Netherlands examined in one study, perc was rapidly transported to groundwater.[45]

Once in groundwater, perc remains stable. The half-life is estimated to be 360 to 720 days, based upon estimated aqueous aerobic biodegradation.[46] Results of a federal survey found that perc was present in 26 percent of U.S. groundwater supplies, with concentration levels as high as 1,500 ppb in some cases.[47] Contamination of groundwater from perc has also been documented in California's Central Valley. Tests conducted in that area show that over 35 percent of 750 wells tested contained perc, many of them at levels higher than the permissible limit. Dry cleaning was found to be the likely source of contamination in 20 out of the 21 wells that were tested extensively.[48] Perc contamination has also been documented in Westchester County, New York. Tests on perc contaminated wells conducted by the New York State Department of Environmental Conservation in 1991 revealed that a well serving a local dry cleaner contained 480 ppb of perc. A neighboring well had 6,000 ppb. The state's maximum threshold is 5 ppb.[49] The state maintains that the contamination was caused by the dry cleaner.

Chlorinated hydrocarbon releases into groundwater, including those involving perc, often form globules, pools, or layers of the chemical. These are known as dense non-aqueous phase liquids (or DNAPLs), which are a source of high concern with respect to groundwater contamination. Due to its solubility and high specific gravity, perc is prone to forming DNAPLs.[50] Toxic concentrations are extremely low.[51] DNAPLs are hard to detect in water, difficult to characterize, and difficult to capture during cleanup. DNAPL flow may occur at right angles to or against the direction of water motion.[52] Once DNAPLs form in groundwater, they can continue to contaminate the groundwater for several years. In addition, it is extremely difficult for conventional pump and treat groundwater remediation systems to meet strict drinking water standards.[53]

Once a site is found to be contaminated, several steps have to be taken. First, the direction of groundwater flow has to be determined. Users of the water then have to be given an alternate supply such as bottled drinking water, and/or provided with water filters. The contaminated soil is then excavated and taken to an appropriate disposal facility. Lastly, the contaminated water is pumped out of the ground and through an air stripper, where the perc will volatize when it reacts with the air. The vapors are filtered to minimize air emissions, and the decontaminated water is returned to the groundwater supply. The costs associated with such cleanups can be very high. In some instances, it is more economical to simply abandon the aquifer and continue with the alternate water supply indefinitely.[54]

Disposal of Perc-Contaminated Products

The still bottoms, filtered muck, and used filter cartridges produced by the dry cleaning process become part of the waste stream. These by-products are classified and manifested as hazardous waste. Prior to development of methods to detect perc and other chlorinated solvents at low levels, disposal in landfills was considered safe. Now, however, disposal must follow federal, state, and local guidelines. Depending upon the size of the dry cleaning operation, landfill disposal of perc by-products may or may not be legal. For larger dry cleaners, disposal products containing perc may not be disposed of in a landfill. Dry cleaners who produce less than 220 pounds of perc waste per month are classified as small quantity generators. They are allowed to dispose of waste products in a licensed landfill, as long as they notify the trash hauler and the landfill that the load contains low-level hazardous waste.[55] For larger dry cleaners, the most common method of disposal is to send the waste to a licensed reclaimer or a permitted incinerator. Most dry cleaners use an off-site service to dispose of waste products.

Safety-Kleen, a national hazardous waste disposal service company, is used by many dry cleaners. Safety-Kleen reclaims perc from filters and still bottoms before incinerating the residuals. Filters are cut in half and any remaining perc is extracted. Scrap steel is then collected from the filters, and recycled to make barrels. Still bottoms are further distilled to extract perc.

Safety-Kleen reports that there are three primary markets for recycled perc.[56] Although reclaimed perc can be sold back to dry cleaners, perc statistics indicate that less than 5 percent of perc used in dry cleaning is recycled.[57] The remainder of reclaimed perc is sold as a degreaser or as an adhesive or aerosol to industry. Safety-Kleen reports the following breakdown for the markets which buy their reclaimed perc: 60 percent dry cleaning, 15 percent vapor degreasing, 5 percent carriers for adhesives, and 20 percent for making freon (though this is now phased out).[58] Once the perc has been reclaimed and scrap steel obtained, the remaining material is incinerated, or sold to cement kilns for incineration, at temperatures greater than 2,700 degrees Fahrenheit. Incineration of materials containing perc can lead to further air emissions and incinerator ash, which must be disposed of as hazardous waste. Perc had been detected in stack effluents from municipal and hazardous waste incinerators.[59] Additional impacts of perc incineration are not easily discernible from total incinerator emissions because many products are incinerated together.

Transportation of Perc

Transporting perc from manufacture sites to the point of use increases the possibility of accidents which may lead to spills. Spills may occur into the ground, water, or air during storage of perc at the point of manufacture, transfer to the delivery vehicle, in transport, or transfer from the vehicle to the dry cleaning machine tank.

Canada has recorded a total of 34 perc spills, totaling 123,074 liters, since 1977 under a system of voluntary chemical spill reporting.[60] Of this amount, 87 percent was spilled from industrial plants and storage facilities, while the remaining spills occurred during transport. The amounts of each spill range from less than one liter to 43,652 liters. Spills require expensive emergency remedial action to contain them, as well as cleanup of soil or groundwater contamination if it occurs. The point of presenting spill data is to demonstrate that risks exist from transportation of perc that are not present for wet cleaning.

Summary of Perc Impacts

Each of the above impacts of perc use by themselves may not represent a significant risk. However, in aggregate, they present cause for concern. In their report on perc and its environmental impacts, the Canadian Government has concluded the following:[61]

> ...on the basis of available information, tetrachloroethylene [perc] is entering the Canadian environment in significant quantities but does not result in concentrations that, in general, would be expected to cause adverse effects to aquatic biota or terrestrial wildlife; however, limited data suggest that atmospheric concentrations of tetrachloroethylene may be sufficient to cause adverse effects to some terrestrial plants, notably trees, in Canada. Furthermore, contamination of groundwater and groundwater-recharged surface water in Canada with tetrachloroethylene could be significant, particularly in areas where there has been inappropriate disposal of this substance from dry cleaning facilities and landfills. It has been concluded, therefore, that tetrachloroethylene has the potential to harm the environment.

As previously indicated, this study does not fully examine the environmental impacts from manufacture of perc. Although resource intensive, expanding the scope to include manufacturing would provide a more comprehensive assessment.

Impacts From Energy Requirements

Determining energy requirements is important for a comparative analysis since energy is generally supplied by the combustion of nonrenewable resources, at least in the form of electricity as we have used here. Sources of nonrenewable fuel used to generate electricity are coal, nuclear power, natural gas, or petroleum. Renewable sources include hydropower, wind power, geothermal energy, biomass, and waste-to-energy methods. We do not consider the source of fuel in this analysis, but raise the point to acknowledge that fuel inputs are required for both systems. The system utilizing the lowest amount of energy requirements would pose the least environmental burden in this category.

Electricity consumption can be directly related to certain environmental impacts by the use of emission factors for various pollutants. U.S. EPA has identified national emission factors in grams per kilowatt hour for non-methane hydrocarbons (NMHC), carbon monoxide (CO), oxides of nitrogen (NOx), sulfur oxides (SOx), and particulate matter (PM) based upon kilowatt hours. The formula for calculating pollutants is to multiply the kilowatt hours required to operate the system by the emission factor for each pollutant to determine the level of pollution generated. This is done on a weighted average based upon the fuel source. Table 8 below lists the emission factors for combustion fuels in grams per kilowatt hour. These are then used to determine the total amount of each pollutant emitted based upon the electricity requirements of each system. This result is shown in Table 9.

TABLE 8 - U.S. ELECTRIC UTILITY AVERAGE POLLUTION GENERATION RATES (GRAMS) [62]

Fuel Source	% of total power*	NMHC (g/kWh)	CO (g/kWh)	NOx (g/kWh)	SOx (g/kWh)	PM (g/kWh)
Coal	55.0%	0.0250	0.1483	4.1194	8.7313	0.2292
Fuel Oil	4.2%	0.0427	0.2477	2.3321	5.4416	0.4955
Nat. Gas	9.4%	0.0114	0.2239	2.2281	0.0038	0.0189

*Remainder of the power is generated from nuclear and hydropower sources.

TABLE 9 - AIR POLLUTION EMISSIONS FROM ELECTRICITY USE FOR EACH CLEANING SYSTEM (GRAMS)

Cleaning Process	NMHC	CO	NOx	SOx	PM
Dry Cleaning Total†	235	1,598	36,373	71,120	2,101
Wet Cleaning Total‡	105	716	16,308	31,887	942

†Total emissions for the dry cleaning facility, in grams of pollutant, based upon 14,136 kWh/year.
‡Total emissions for the wet cleaning facility, in grams of pollutant, based upon 6,338 kWh/year.

As shown in the above tables, the dry cleaning process requires more electricity at a given activity level and therefore generates more air emissions of the above pollutants.

Emission factors vary by region and by the type and level of emission control technology employed by electricity generators. The emission factors stated above are national averages. Additional impacts result from the electricity supplied by nuclear and hydropower facilities, but these impacts are disregarded for this inventory.

Impacts From Water Requirements

Water requirements are important to consider because there are costs and environmental burdens associated with water use and wastewater treatment following use. The amount of water used for a unit of cleaning is water that is not available for other uses. In some areas, water is plentiful and high use poses less of a burden than in areas where water is scarce and shortages are a bigger concern.

As shown in the inventory section, wet cleaning requires substantially more water than the dry cleaning process. Because of this, wet cleaning may pose a high burden in areas of the country where water resources are in limited supply. This is one cause of concern for those advocating wet cleaning. The issue may then revolve around attempts to reduce the quantity of water used while still delivering clothes cleaning performance. Aqua Clean has stated that the final rinse of a wash cycle in their machine can be reused for the initial wash cycle of the next load. In this case, the water requirements would be reduced. Ecomat, the privately owned wet cleaning operation mentioned in the Industry Profile Section, is moving to develop an effective water reuse and recycle system, which would significantly reduce water consumption. Since the extent to which this has been or will be used is not currently known, we did not consider it in our inventory.

Also of concern is the additional burden that a wet cleaning facility will place on the local wastewater treatment facility in respect to suspended solids, biochemical oxygen demand, phosphates, and ammonia that the wet cleaning facility will produce. Municipal wastewater treatment facilities are designed to adequately handle these components. The primary concern here is the increased amounts that may be generated. Suspended solids originate from the soils contained in the garments. In a wet cleaning system they are discharged with the wastewater into the sewer system and must be treated. Phosphorus levels in wastewater could increase, depending upon the type of detergent used. Environment

Canada is using phosphate-free detergents,[63] which are not expected to pose an additional treatment burden. This is only an issue if a POTW is already near capacity,[64] and would become more of an issue if the entire garment cleaning system switched to wet cleaning. In addition, concerns have been raised regarding the spotting agents used. We assume that the spotting agents are generally the same for both dry and wet cleaning. However, in wet cleaning, they are rinsed from the clothes during cleaning and discharged into the sewer system. This is an area where future research is needed in order to determine if there are any health or environmental impacts. POTW experts interviewed for this study were not concerned with this issue because of the minute amounts of spotting agents being used relative to the entire amount of wastewater being treated by POTWs.[65]

In the dry cleaning system, suspended solids are captured and disposed of as a hazardous waste. Therefore, they have no impact on a publicly-owned treatment works (POTW). However, if the separator water is disposed of into the sewer system, the perc contained in this water has the potential to leech through sewer pipes and contaminate groundwater supplies (see Perc Impacts on Groundwater above). For a discussion of separator water and POTWs, refer to the section which discusses Regulations. Although there are water treatment impacts associated with each system, the impacts are different and cannot be easily compared.

Just as perc manufacturing is not fully addressed within the life cycle boundaries established for this study, the full impacts of water diversion and preparation for use are not fully considered. However, water is supplied by nature and doesn't have to produced, as does perc. In addition, the water used in wet cleaning is a renewable resource in that it is discharged and treated for reuse.

Final Remarks

Both the dry cleaning and wet cleaning processes result in environmental impacts. The impacts from dry cleaning accrue primarily from the use of perc, which results in pollution emissions into the air, land, and water. Dry cleaning requires more electricity to clean garments, but uses a negligible amount of water.

In contrast, wet cleaning results in significantly fewer impacts. Wet cleaning produces no direct air emissions, no hazardous waste, and requires less electricity to clean clothes.

However, significantly more water is required to clean garments. Nevertheless, water is a renewable resource in that it is treated and is available for reuse.

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III. PERFORMANCE ASSESSMENT

Performance requirements define the functionality of the process under analysis.[1] In the case of professional cleaning, performance criteria provide means to determine the extent to which clothes have been cleaned, and, therefore, how well the process fulfills the existing need for professional cleaning. The technical limits of the process, such as available equipment and facilities, affect the nature of the performance criteria. Performance criteria are also affected by customer behavior and social trends. For example, professional cleaning is often viewed as the exclusive method of cleaning expensive, high-quality clothes.[2] The perceived higher value of these types of clothes drives dry cleaners to achieve performance levels which exceed the performance levels for alternative cleaning methods (e.g., home washing) of less valued types of clothing.

Because performance along with price, convenience, and service is a key characteristic customers consider when selecting a dry cleaner, dry cleaners are reluctant to experiment with unproved cleaning processes.[p] Therefore, there is a need for a standard of performance against which innovations can be compared.

It's important to note, however, that much of the perception that professional cleaners are able to do a better job of cleaning garments, is due to the final appearance of the garment. In large part, the final appearance is determined by the pressing and finishing. Therefore, in addition to the cleanliness of a garment, performance criteria should evaluate the final appearance of a garment.

Furthermore, poor performance may have a negative effect on the net impact of the life cycle of clothes.[3] If professional cleaning performs badly, or actually reduces the useful life of clothing, people may retire clothing early leading to increased consumption of clothing and, therefore, excess waste generation and resource use. Therefore, performance criteria should also assess any impact the cleaning process has on the construction of the garment and its fibers.

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[p]For partial results of a C&R Research Services study of characteristics customers look for in a good dry cleaner, see Appendix G.

Technical Performance for Cleaning

There are three main technical requirements that must be achieved for successful textile cleaning.[4] The cleaning process should do the following:

- overcome the soil - textile interaction forces. This is achieved through physical and/or chemical methods;
- transport soil away from the textile, while cleaning and reusing the cleaning medium; and,
- maintain and restore the original attributes of the fabric. These attributes pertain to dye character and fabric finish.

In order to ensure clothes are effectively and efficiently cleaned, a cleaner must consider the following five factors and make adjustments with respect to the specific characteristics of a garment load.[5,6]

- **Soils.** Soils are either water soluble, solvent soluble, or nonsoluble.
- **Textiles.** Textiles are either natural and, therefore, water sensitive, or artificial and heat sensitive. Other factors to be considered with respect to textiles are their resistance to solvent and mechanical stresses.
- **Detergency.** The cleaning detergent must overcome the soil - textile interaction force and suspend the soil such that it does not resettle on the fabric.
- **Transport Medium.** The transport medium should be able to be purified and reused.
- **Process.** Process involves the balance of physical and chemical actions, time, and temperature.

Note on Fibers and Garment Shrinkage

Determining the expected response of a textile to any external variable such as solvent, water, detergent or heat is practically impossible because there is no consistent fiber structure.[7,8] For example, the polyester family of textiles has thousands of fiber structure variations, and cotton grown in California my be very different structurally from cotton grown in Georgia.[9] For this reason, textile experts classify textiles into families and can predict characteristics in only a very general sense. Every effort has been made to qualify the following findings as to which textile has demonstrated a particular characteristic, yet the reader should remember that not every fabric will react to an external variable in a similar manner.

Furthermore, the penetration of any liquid into the pores of a fiber can result in the swelling of the fiber and changes in its structure.[10,11] As a fiber swells it will expand in diameter and shorten in length. The decrease in the fiber length, area and/or volume results in the garment shrinking.[12] In cotton, linen and rayon, the shrinkage is due to the fibers swelling and releasing the tension of the textile which previously had been stretched and sized. In wool, shrinkage is due to a combination of fibers swelling, heat and friction. In this case textile tension is not released, but rather fibers enmesh and fuse together.[13] As stated previously, the exact characteristics of the swelling and shrinkage that occurs for any one textile is a function of many variables including fiber type, liquid type, and garment construction.

Perc as a Cleaning Agent

Chlorinated organic solvents are used in dry cleaning because they have many characteristics which result in superior cleaning.[14] Perc, in particular, has the optimal combination of characteristics. The first of these characteristics is perc's ability to dissolve organic stains such as oils, greases, fats, and waxes. The Kauri Butanol (KB) number is a relative measure of a solvent's ability to dissolve organic soils. The preferred range for clothes cleaning is between 30 and 100. Any solvent value below 30 is too weak to effectively clean clothes, and a value above 100 may cause dyes to run. Perc has a KB value of 92.

A second characteristic is that perc does not readily penetrate the fiber pores of certain textiles such as wools and cottons.[15] This reduces fiber swelling and the potential for garment shrinkage. Perc further reduces the potential for shrinkage because it evaporates quickly during the drying and extraction stages minimizing a garments exposure to heat. Finally, perc is non-flammable and easily distilled for reuse.

Because perc and other like solvents used in dry cleaning cannot dissolve water-soluble soils such as blood and perspiration, perc cleaning requires the addition of small amounts of water. The water is combined with detergent and added to the perc in the form of a charging agent. The detergent reduces the surface tension of the water such that it can mix uniformly with the perc, dissolves the water-soluble stains and suspends the soil in the perc solution. Water soluble soils can also be treated during the spotting stage using water-detergent solutions.

Water as a Cleaning Agent

Because of its limited application to date as a primary professional-cleaning method, few studies have been done on the effectiveness of wet cleaning in this capacity. The existing studies have measured customer satisfaction and not the wet cleaning method's technical performance.[q]

Water penetrates the fiber pores of cottons and wools more deeply than perc and, therefore, has a greater potential to swell fibers and cause shrinkage of garments made from these textiles.[16] For the majority of fabrics, water does not dissolve or weaken fibers and does not cause bleeding of dyes. However, water has been known to cause dye bleed in silks. Water is compatible with commonly used laundry detergents. Furthermore, many of these detergents use optical brighteners which result in an overall brightening of garment colors, yet they do not increase soil removal or result in a cleaner garment.[r]

Because water does not dissolve organic soils, nonchlorinated solvents are used to treat these stains. This method is, in effect, very similar to the treatment of water-soluble stains during the spotting stage of the dry-cleaning process.

Development of a Performance Protocol

There are several testing standards and guidelines for evaluating the performance of dry cleaning methods.[17] One example is the International Fabricare Institute's (IFI) Cleaning Performance for Quality Control.[18] For a dry cleaner to be evaluated according to these criteria, the IFI will first send the dry cleaner a piece of fabric with several different types of stains on it. The dry cleaner then processes the fabric sample and returns it for analysis. The IFI analyzes the fabric sample against its set of performance criteria evaluating such elements as percent whiteness and percent yellowness. The American Association of Textile Chemist and Colorists is another group which has developed performance criteria for dry cleaning.[19] These criteria are historical baselines which provide guidelines for trouble shooting cleaning problems. They are not technically or scientifically based standards of cleanliness.[20]

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[q]The reader is reminded that for this study, wet cleaning is defined as a combination of 70 percent machine wet cleaning and 30 percent multiprocess wet cleaning.

[r]According to Dr. Charles Riggs of Texas Woman's University, Department of Fashion and Textiles, optical brighteners are also available for cleaning solvents such as perc but are not generally used (Riggs 1995).

Although individual organizations have created protocols, there is no uniform protocol for the dry cleaning industry.[21] For this reason, in 1994 the EPA's Design for the Environment's Dry Cleaning Project (DfE) requested submission of proposed protocols which could be utilized during their ongoing study of perc dry cleaning and wet alternatives. Dr. Charles Riggs of the Texas Woman's University, Department of Fashion and Textiles, speculates that the resulting protocol will most likely be a "moving" protocol which combines elements from several proposals and changes over time as more is learned about wet cleaning.[22] The resulting protocol will most likely include criteria for evaluation within the following generally accepted categories:

- colorfastness;
- soil removal;
- odor;
- fiber damage;
- shrinkage; and,
- hand (feel).[23, 24]

Dr. Riggs has submitted a proposal to the EPA for a two-step protocol designed to evaluate four existing perc dry cleaning alternatives and two new alternatives.[25] The first portion of the protocol screens each technology with respect to fabric type and soil type. Screening evaluations will be performed on swatches of wools, silks, and rayons dirtied with artificial soils, and swatches of other fabric types dirtied with natural soils. The swatches will be evaluated against criteria such as shrinkage and fiber damage. Those fabric types which pass the first step, will be evaluated further utilizing a panel of wearers. According to Dr. Riggs, the proposed protocol is more extensive than existing protocols. For example, his proposed protocol includes a test for sanitation which did not previously exist.

The Protocol Debate

Although measures have been taken to develop a single protocol for comparative testing of dry and wet cleaning, a debate exists over the need for such a protocol and, if one were to be developed, its methodology. The main question is whether the baseline for cleanliness should be that achieved with perc. Jodie Siegel, a textile engineer at the University of Massachusetts–Lowell and a participant in the DfE project points out that when perc was introduced there was not extensive testing to ensure that perc cleaned as well as the existing petroleum solvents it would replace.[26] The industry has previously used traditional textile tests performed on fabric swatches to evaluate cleanliness and has never developed testing methodology for testing actual garments. Advocates of wet cleaning argue that perc should not be the benchmark for cleanliness, rather an acceptable standard of cleanliness is the baseline.[27, 28]

Most of the criticism of wet cleaning's ability to clean is directed at the multiprocess methods of partial immersion, and steam and tumble cleaning.[29]

Findings on Performance

Although no agreed upon protocol exists, practitioners of both dry and wet cleaning, scientists, and other interested parties have continued to assess the performance of both dry and wet cleaning processes. These assessments generally consist of two types of evaluation; technical performance and customer satisfaction. The following is a summary of performance findings for perc dry cleaning and the alternative wet cleaning.

Technical Performance of Perc Cleaning

During the drying cycle, perc is removed from the garment in one of two ways.[30] The first way is the evaporative loss of perc from the *surface* of the garment. The second, the removal of perc from the garment's *fiber pores*, involves the perc diffusing from the interior of the fiber to the fiber surface; this process is very specific to fiber structure, garment construction, machine technology and machine operation.[31,32,33] To ensure that all the perc is removed from a garment, the dry cleaning professional should use the latest machine technology and determine drying parameters for the individual tyes of garment.[34] However, since garments are usually cleaned and dried collectively and parameters are not determined for individual garment needs during dry cleaning, it is possible for a garment to have perc trapped in its fiber pores.[35]

Dr. Hans-Dietrich Weigman has studied perc and its interaction with polyester garment fibers.[36] Dr. Weigman found that increasing the temperature during drying increases the evaporative losses of perc. However, it also increases the absorption of perc into the garment fibers. With increased temperatures, the perc is actually being drawn more strongly and deeply into the fiber pores. Dr. Weigman treated garments with perc at elevated temperatures to induce perc sorption. He then measured the perc loss that occurred as the perc which had diffused to the interior of the fibers was released. After

100 days only 40 percent of the perc which was held in the fiber pores was able to diffuse to the surface of the fibers and evaporate.

Customer Satisfaction of Perc Cleaning

Table 10 is an excerpt from a small survey of Chicago residents done by C&R Research Services. The table summarizes the survey respondents' ratings of their perc dry cleaners' on relevant cleaning performance issues.

TABLE 10 - SURVEY RESULTS RATING PERC DRY CLEANERS' PERFORMANCE [37]

Rating of How Your Current Dry Cleaner Performs on ...	Percentage of Responses above 5	Average Score [1 (poor) to 7 (excellent)]
"Clothes Look Good"	94%	6.41
"Clothes Feel Fresh"	92	6.31
"Stain or Spot Removal"	89	6.09

On a scale from 1 (poor) to 7 (excellent), each of the qualitative criteria received a score within the very good to excellent range which indicates that those surveyed were satisfied with the performance of perc cleaning.

Technical Performance of Wet Cleaning[5]

The major issue with water as a cleaning medium revolves around its removal from the garments after the cleaning process. Water has a higher Heat of Vaporization than perc. Therefore, it does not evaporate as easily as perc. In order to evaporate the water, either higher temperatures or longer drying times are required. Heat applied to natural fibers can result in shrinkage while artificial fibers can be destroyed by heat. Practitioners of wet cleaning say that since shrinkage results from over drying a garment, controlling the extent of drying will eliminate shrinkage completely.[38, 39, 40] Consequently, a wet cleaner must pay special attention to residual moisture content in the garment while drying. For certain garments this may require them to be drip dried. However, most garments can be successfully handled by a specialized drying machine programmed for the specific garment's needs. For example, the American ADF 50 machine used by Environment Canada is programmable for residual moisture contents of 80–100 percent.[41] Wet

[5]The credibility of the following information on water-based cleaning performance has been questioned on the grounds that it is primarily from sources with a financial interest in water-based cleaning. Throughout the study, the authors have made every attempt to include information from all publicly available sources and welcome any additional information on water-based cleaning from testing entities or practitioners.

cleaning practitioners find that in addition to using these high technology machines to avoid garment shrinkage, they must also sort garments more carefully than they would when using perc. This often results in the need to run more loads of smaller sizes. Wet machines may also allow a cleaner to expand the types of garments that they can clean. For example, most perc-based cleaners are not able to clean leather and suede garments because perc destroys the textile's natural oils and stiffens the garment.[42] Instead, dry cleaners typically send leather and suede garments to a specialist for cleaning. However, a wet machine with normal detergents and a specially designed finishing agent can successfully clean leather and suede without harming their natural oils. A second example of a garment which often can not be perc cleaned but which can be wet cleaned is a beaded garment. Perc, unlike water, can dissolve or melt beads, leaving behind stains on garments which often cannot be removed.[43] Elisabeth Winter, who operates a 100 percent wet cleaner in Austria, has experienced a reduction in problems relating to dissolved or loosened buttons, patent leather trimmings turning brittle, and glued pieces becoming unstuck since converting to wet cleaning.[44]

As part of the EPA's Design for the Environment Dry Cleaning project, the EPA did a Multiprocess wet cleaning performance study from November 1992 through January 1993.[45] The study was performed at the Neighborhood Cleaners Association's New York School of Dry Cleaning and at the University of Georgia Textiles, Merchandising, and Interiors Department. One of the tests within the project was a technical wear study of 13 unique garment types. A panel of wearers were given garments to wear and clean over a period of four weeks.[46] There were three samples of each of the 13 unique garment types; one sample was dry cleaned, one was wet cleaned and one was never worn or cleaned. The technical wear study compared the shrinkage, stretching, color change and odor of the three samples for each of the 13 garments. The EPA strongly cautions against inferring too much from the technical wear study mainly because of the small sample size and short duration of the test. However, the study found no appreciable difference between the garments with respect to shrinkage, stretching, color change and odor.

Customer Satisfaction with Wet Cleaning

The DfE study also included a general satisfaction survey and a consumer satisfaction test of the above-mentioned 13 garment types.[47] During the general satisfaction survey, customers received their garments from the professional cleaners with questionnaires attached to each garment. The customer was not informed whether the garment had been wet cleaned or dry cleaned. The questionnaire asked the customer to judge color, feel, smell, etc. More than one third of the cards were returned, 350 out of 900, and both processes received positive and negative comments. However, there was a statistically significant preference for the wet cleaned clothes.

For the consumer satisfaction test, an independent group of consumers judged the cleanliness and acceptable character of the 13 garment types at the end of a four-week wearing period.[48] Again, both negative and positive comments were generated for both types of cleaning. However, in this study, no statistically significant preference was identified.

For the months of June, July, and August 1994, Environment Canada surveyed customers who had used its Green Clean[t] wet cleaning demonstration project.[49, 50, 51] Environment Canada received 177 survey responses representing 17 percent of all customers and 12 percent of all garments. Of those that responded, 97 percent indicated that the clothes were clean overall, and 98 percent responded that they would have their clothes wet cleaned again. Over 80 percent responded positively to all questions. The Green Clean Project also had 13 percent of its customers return business within the three month study period. Presently the Green Clean project is cleaning approximately 50 garments per day. To date, the Green Clean project has rejected only two garments (<1 percent). "Two identical blouses were tested for dye run and when the cleaner determined that the dye was not fast, blouses were rejected. The manufacturer refunded the customer."[52] Five (<1 percent) customer claims have been filed[u] and 31 (<2 percent) garments generated negative comments. A total of 1460 garments were successfully cleaned.[53]

[t]The Environment Canada's Green Clean Project is a three-year voluntary project to examine reducing the use of perc. The project is based on a Memorandum of Understanding between the Korean Dry Cleaners Association, Ontario Fabricare Association, the Ontario Ministry of Environment and Energy, and Environment Canada. The customer satisfaction data presented was collected at their Green Clean Depot. The Depot gathers information on garment type, garment textile, customer satisfaction, claims and percentage of garments successfully cleaned.

[u]Complaints listed on the five customer claims were "shrinkage & matting," "shrinkage," "stains & dye running," "cracking" (for a polyester jacket), and "dye ran from leather trim."

Elisabeth Winter of Austria states, "The results of wet cleaning are 'visible, palpable, and smellable.' Brilliance and freshness of colours are unparalleled, and both the good feel and the fresh smell of the clothes speak for themselves."[54] She further states that the satisfaction of her customers has increased since she switched to wet cleaning, and that customers are particularly pleased with the color and smell of the clothes. The rate of complaints, however, has remained unchanged.

Final Remarks

A comparison of the performance capabilities of dry and wet cleaning is inconclusive in determining any real advantage of one system over the other. Because fiber structure and garment constructions vary so greatly, no specific performance results can be predicted for either system. Both dry cleaning and wet cleaning have demonstrated clear advantages and disadvantages. However, it is clear that the wet cleaning method has improved significantly with the introduction of new machine technology. With continued development of wet cleaning techniques and additional experience cleaning an assortment of garments, wet cleaning shows potential to effectively clean those garments which traditionally have been considered "dry clean only."

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[4]Dr. Manfred Wentz, Fabricare Legislative and Regulatory Educational Organization, "Clearing the Air on Clean Air," The University of Tennessee Center for Industrial Services, Tennessee Department of Environment and Conservation, Video of Teleconference (May 12, 1994).
[5]Dr. Manfred Wentz 1994.
[6]G. Jakobi, and A. Lohr, *Detergents and Textile Washing: Principles and Practice*, (New York: VCH Publishers, 1987) p. 7.
[7]Personal communication with Dr. Charles Riggs, Texas Woman's University, Department of Fashion and Textiles, March 23, 1995.
[8]Personal communication with Leon Moser, Executive Specialist, North Carolina State University, College of Textiles, March 24, 1995.
[9]Moser 1995.
[10]Riggs 1995.
[11]Moser 1995.
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[13]Grace G. Denny, *Fabrics*, (Philadelphia: J.B. Lippincott Company, 1953): 162.
[14]Katy Wolf, "Case Study: Pollution Prevention in the Dry Cleaning Industry: A Small Business Challenge for the 1990s," *Pollution Prevention Review* (Summer 1992).
[15]Moser 1995.
[16]Ibid.
[17]Riggs 1994.

[18]Personal communication with Elke Carry, International Fabricare Institute, December 14, 1994.
[19]Personal communication with Jo Patton, Center for Neighborhood Technology, October 21, 1994.
[20]Moser 1995.
[21]Riggs 1994.
[22]Ibid.
[23]Patton 1994.
[24]Riggs 1994.
[25]Ibid.
[26]Personal communication with Jodie Siegel, Toxic Use Reduction Institute, University of Massachusetts-Lowell, January 31, 1995.
[27]Siegel 1995.
[28]Patton 1994.
[29]Siegel 1995.
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[31]Riggs 1995.
[32]Moser 1995.
[33]Dow Chemical, "A Basic Handbook for Drycleaners," p. 11.
[34]Moser 1995.
[35]Ibid.
[36]Weigmann 1992.
[37]C&R Research Services 1994.
[38]Richard Simon, "Ecoclean-The Environmental Alternative to Dry Cleaning," Fact Sheet, Ecoclean International Inc.
[39]Elisabeth Winter, "Wet Cleaning With the Miele-Kreussler Textile Cleaning System," Fact Sheet, (July 15, 1994).
[40]Personal communication with Toby Brodkorb, Engineer, Environment Canada, December 12, 1994.
[41]Brodkorb 1994.
[42]Riggs 1995.
[43]Daniel Eisen, "Beaded Garments," *The Bulletin* 44, no. 10 (December 1994): 9.
[44]Winter 1994.
[45]U.S. EPA, *Multi Process Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and an Alternative Process,* Executive Summary, EPA 744-R-93-004, (1993).
[46]U.S. EPA 1993.
[47]Ibid.
[48]Ibid.
[49]Personal communication with Mary Margaret Crapper, Environment Canada, November 21, 1994.
[50]Brodkorb 1994.
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[52]Ibid., p. 22.
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[54]Winter 1994.

IV. ECONOMIC ANALYSIS

In comparing dry cleaning with a wet cleaning alternative, it is important to analyze the economic costs and benefits of the alternative system. Most importantly, professional cleaners will need to be assured that a new alternative system can clean clothes at a price competitive with dry cleaning, otherwise they will not invest in that technology. Similarly, an alternative system may result in similar profitability but may be preferable because it requires less up-front capital expenditures. To address these questions, we will compare the costs of running a model dry cleaning facility with the costs of running a model wet cleaning facility.

In conducting the economic analysis, data for the model dry cleaning facility is taken from the EPA report titled "Multiprocess Wet Cleaning; Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process." For a more thorough explanation of this data, readers are encouraged to refer to this document. Using the general framework established in the EPA report, original data used to analyze the wet cleaning system was obtained from Aqua Clean System manufacturers, Environment Canada staff involved in the Green Clean demonstration project, and Ecomat (a practicing wet cleaner).

A preliminary look at the prices charged by existing wet cleaners suggests that wet cleaning can compete with dry cleaning. Table 11 summarizes the prices.

TABLE 11 - PRICE COMPARISON BETWEEN DRY AND WET CLEANERS FOR SELECT GARMENT TYPES[v]

	Ecomat[1]	Env. Canada[w]	Dry Cleaning[2]
Plain Three Quarter Coat	$10.00	$ 8.56	$ 9.00
Trench Coat (w/lining)	18.50	n.a.	16.00
Full Length Overcoat	15.50	n.a.	11.00
Suits	8.75	7.81	8.00
Tuxedo	16.50	10.71	9.50[3]
Pants	4.50	3.55	3.75
Jackets	5.50	4.26	4.50
Sweaters	4.50	3.55	4.00
Dress	6.00	6.41	8.00
Skirt	5.00	3.55	3.75
Two-Piece Silk Suit	16.00	10.68	10.50
Silk Tie	4.50	3.93	3.00
Shirts	1.80	1.25	1.65

Several important economic factors are beyond the scope of this analysis but are worthy of mention in this section. Foremost among them is that wet cleaning may be less attractive because the overall process may take longer. For example, wet cleaning relies on a short, controlled drying cycle. Certain garments, such as a coat with two linings, are not fully dried by this controlled drying process and must be hung out to dry. Consequently, wet cleaning establishments may be unable to offer "same-day" service. To the extent that customers value same-day service, this may put wet cleaners at a competitive disadvantage in the marketplace.

Conversely, wet cleaners may be able to compete favorably with dry cleaners by catering to "green" consumers. That is, some consumers may drive a little further to a wet cleaner, may be willing to wait a little longer for their clothes to be cleaned, and/or may pay a little more to have their clothes wet cleaned because they believe it is better for the environment and it reduces their exposure to a potentially dangerous chemical.

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[v]Author's calculations for Environment Canada are from price list supplied by Mary Margaret Crapper, Environment Canada, on February 1, 1995, using the exchange rate $1.3955 Canadian are equal to $1 US on February 8, 1995. Prices from Ecomat were supplied by Diane Weiser, CEO and President, EcoFranchising, Inc. Prices for Dry Cleaning were supplied by Mike Astorino, Darien Fabricare.
[w]Author's calculations from price list supplied by Environment Canada on February 1, 1995 using the exchange rate $1.3955 Canadian are equal to $1 US on February 8, 1995. (Personal communication with Mary Margaret Crapper, Environment Canada, February 1, 1995.)

Methodology and Basic Data for Model Facility Analysis

Data used to analyze the costs of operating the model dry cleaning facility are based on a report written by the U.S. EPA titled, "Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process." The model dry cleaning facility is defined as one using a 50-lb., dry-to-dry, closed-loop machine with a refrigerated condenser. This modern dry cleaning machine is estimated to clean 30,000 lbs. of clothes per 55 gallon drum of perc. EPA used the same assumption of perc mileage, based on an estimate provided by Kim Gustufson of VIC manufacturing and John Stephens of Standard Pressing Machine Company, Inc.[4] However, other machine manufacturers report higher perc mileage rates on many newer machines. Consequently, the cost impacts of higher perc mileage will be discussed in the sensitivity analysis at the end of this section (the reader may also wish to refer to the discussion of perc mileage in Section I: Inventory Analysis).

The model wet cleaning facility is based on the use of a 50-lb. wet cleaning machine. Based on preliminary results from the Environment Canada demonstration project, it is assumed that our model facility will be able to clean 70 percent of incoming garments in wet clean machines. The remaining 30 percent will be assumed to be cleaned by multiprocess wet cleaning. Other assumptions used in the model facility analysis of both the wet and dry facilities include:

1. Average net revenue of the model facility is $260,000 per year. While EPA acknowledged that the average net revenues of dry cleaners varied widely, they felt that an assumption of $260,000 a year would represent a typical, successful dry cleaner. The EPA derived the exact figure after discussions with industry groups, equipment manufacturers and distributors, and dry cleaners.[5]

2. Base price for dry cleaning a suit or full garment is $7.17 per garment. This represents the cost to clean a full suit (or two half garments such as a jacket and pair of pants).[6] The analysis is aimed at comparing wet cleaning technology with dry cleaning technology. However, because shirt laundering is similar in both wet and dry cleaning, it has been excluded from the comparative analysis performed here. Consequently, the $7.17 figure does not reflect the cheaper price paid for shirt laundering.

3. Based on the first two assumptions, the model facility will clean ($260,000 / $7.17 =) 36,262.2 garments per year. This translates into 697.35 garments per week.

4. Each garment is assumed to weigh an average of 2.205 lbs. Thus, the facility cleans an average of (697.35 x 2.205 =) 1,538 lbs of clothes per week or 79,958.2 pounds of clothes per year.[7]

5. Assuming the dry cleaner is running the 50-lb. dry cleaning machine at 90 percent of capacity, the average load dry cleaned will be 45 lbs. In order to clean 1,538 lbs. of clothes per week, the cleaner will need to run (1538 / 45 =) 35 loads per week.[8] For the wet cleaner, only 70 percent of clothes will be run through the Aqua Clean Machine (1076 lbs. of clothes per week). Based on the manufacturers recommendation, the 50-lb capacity Aqua Clean machine is only loaded to 55 percent of capacity, for an average load size of 27.5 pounds per load.[9] Thus, the wet cleaner must run (1,076 / 27.5 =) 40 loads per week. All loads in the 30-lb capacity Aqua Clean dryer are also assumed to be 27.5 pounds loads on average. Drying all wet cleaned clothes, including those not put in the Aqua Clean washer (a total of 1538 pounds per week) will require running 56 loads per week in the dryer.

6. The dry cleaning facility cleans 35 loads per five day work week (7 loads per day). Assuming that each load runs for 45 minutes, then the dry cleaning machine is in use for 26.25 hours per week.[10] For the wet cleaning facility, an average load in the Aqua Clean washer takes 30 minutes and an average load in the Aqua Clean dryer takes 11 minutes.[11] Thus, the Aqua Clean washer will be in use for 20 hours per week (40 loads x 30 minutes) while the Aqua Clean dryer will be in use for 10.27 hours per week (56 loads x 11 minutes).

Summary Results of Model Facility Analysis

Based on the assumptions just explained, the cost of operating a model dry cleaning establishment was compared with the cost of operating a similarly sized wet cleaning shop. The results of this analysis are presented in Tables 12 and 13. For further details, refer to Appendices C and D.

The model facility analysis shows that the cost of operating a wet compared to a dry cleaning facility is comparable. In fact, it was slightly cheaper to operate the wet cleaning facility. In their study of multiprocess wet cleaning, the U.S. EPA chose to discount investments using a 7 percent interest rate. This choice was based on specific agency guidance used for economic analysis involving private investment.[12] At a 7 percent discount rate, the wet cleaning facility was $1,030 cheaper to operate. Differences in operating costs ranged from $710 using a 5 percent discount rate to as high as $1,368 using a 9 percent discount rate. In all cases, the wet cleaning operation cost slightly less to operate. For a line by line description of the individual cost categories used to derive this table, please refer to Appendix C and D.

TABLE 12 - SUMMARY OF RESULTS OF MODEL FACILITY ANALYSIS

Dry Facility	i=5%	i=6%	i=7%	i=8%	i=9%
Revenue	$260,000	$260,000	$260,000	$260,000	$260,000
Operating Costs	$240,132	$241,095	$242,093	$243,125	$244,187
Profit	$19,868	$18,905	$17,907	$16,875	$15,813
Wet Facility					
Revenue	$260,000	$260,000	$260,000	$260,000	$260,000
Operating Costs	$239,422	$240,227	$241,063	$241,928	$242,819
Profit	$20,578	$19,773	$18,937	$18,072	$17,181
Which Has Greater Profit?	Wet	Wet	Wet	Wet	Wet
Difference in Profit	+$710	+$868	+$1,030	+$1,197	+$1,368

Results of Model Facility Analysis for Select Categories

Professional cleaners, regardless of the clothes cleaning technology they choose, must make certain basic expenditures including building rent, office supplies, bags, hangers, pressing equipment, etc. These costs do not vary depending on cleaning technology; and therefore are of limited interest to this study. While the magnitude of these costs will determine how profitable a cleaner will be, they do not tell us whether one type of cleaner will be more profitable than another. It more appropriate to analyze categories such as capital equipment, cleaning agent purchases, electricity use, water, and labor because they vary significantly depending on the technology used. The chart below details how these cost categories differ for the model wet and dry cleaning facilities. Capital costs are annualized using a 7 percent discount rate. All figures are yearly costs.

TABLE 13 - SUMMARY OF RESULTS FOR SELECT CATEGORIES

I. Capital Costs	Dry Cleaning	Wet Machines
• 50-lb. dry-to-dry machine	$4,979	---
• Aqua Clean System (50-lb. washer/30-lb. dryer)	---	$3,291
• Refrigerated Condenser	985	---
• Aerocooling Unit	198	---
• Spray Gun	---	165
• Scrubbing Board w/Industrial Sink	---	21
Total Capital Costs	$6,062	$3,477
II. Cost of Cleaning Agents (per year)		
• Perc Use	$ 762	---
• Charging Detergent	1,679	---
• Aquasafe Detergents	---	$1,713
• Aqua Clean Prefinish Sizing	---	4,031
• Filter Purchase	1,676	---
• Filter Disposal	2,050	---
• Separator Water Disposal	684	---
• Still Bottoms Disposal	841	---
Total Cost of Cleaning Agents	$7,692	$5,744
III. Electric Use (cost per year)		
• 50-lb. dry-to-dry machine	$ 677	---
• 50-lb. Aqua Clean Washer	---	346
• 30-lb. Aqua Clean Dryer	---	132
• Refrigerated Condenser (Winter Months)	351	---
• Aerocooling Unit (Summer Months)	32	---
Total Electric Costs	$1,060	$478
IV. Water Use (cost per year)		
• 50-lb. dry-to-dry machine	negligible	---
• 50-lb. Aqua Clean Washer	---	$729
• Multiprocess Wet Cleaning	---	40
Total Water Costs	negligible	$769
V. Labor (cost per year)		
• Front Counter Help	$31,200	$ 31,200
• Dry Clean Spotting	15,600	---
• Wet Clean Spotting	---	10,364
• Pressing	27,197	36,262
• Manager	25,000	25,000
Total Labor Costs	$98,997	$102,826

Capital Costs

Dry cleaning involves a significantly greater up-front capital expenditure. For a dry cleaning facility, purchase of a 50-lb. dry-to-dry closed-loop machine, refrigerated condenser, and aerocooling unit costs an estimated $54,368. Conversely, purchase of a 50-lb Aqua Clean washer and dryer, spray gun, scrubbing board, and industrial sink for wet cleaning costs $31,743. Amortizing these capital costs over the equipment's estimated useful life yields a yearly capital cost of $6,062 for dry cleaning and $3,477 for wet cleaning. For more information concerning estimated useful life and other assumptions needed to make these calculations, refer to Appendices C and D at the back of this report.

Cost of Cleaning Agents

The annual cost of cleaning agents for dry cleaning is significantly more expensive than wet cleaning. Roughly half of the cost of cleaning agents in dry cleaning, $3,575 of a total annual cost of $7,692, is spent on hazardous waste disposal. While wet cleaning detergents are significantly more expensive to use, they are unregulated by EPA and thus carry no special disposal costs.

Electric Use

Use of a wet machine requires about half of the electric use of a dry cleaning machine. Much of the difference is attributed to the use of the refrigerated condenser and aerocooling unit. That is, energy requirements for pollution control equipment make dry cleaning significantly more energy intensive than wet cleaning. This difference would be greater in warmer areas where the more energy intensive refrigerated condenser is needed for a longer part of the year. Conversely, in cooler climates the difference would be smaller.

Water Use

While both processes use water for steam generation in spotting and pressing, water use by wet and dry machines differs greatly. Water use attributed directly to dry cleaning is negligible. An estimated 12 gallons per year is used in the refrigerated condenser, and an estimated 54 gallons are used each year for charging detergent to be added to the perc solvent. Conversely, the wet cleaning facility will use an estimated 219,531 gallons of water per year. At an estimated cost of $2.62 per 100 cubic feet, the wet facility will spend $769 more on water each year. In areas where water is scarce, and hence more expensive, the difference will be greater. However, the Aqua Clean washer does have a tank which is capable of storing water from the last rinse cycle. By reusing this water in the next wash cycle, water use could be lowered and costs would subsequently be reduced. For further discussion, see the section on water use in the sensitivity analysis (page 100).

Labor

Wet cleaning is estimated to have a greater total labor cost: $102,826 compared to $98,997. While less labor is needed for spotting, pressing time is increased. The net result is an increased cost of labor in a wet facility by $3,829 over that of a dry cleaner. Given that labor costs represent over 40 percent of the total annual operating costs of a professional clothes cleaner, assumptions about labor dramatically affect the results of the model facility analysis.

Sensitivity Analysis

Labor

Considerable disagreement exists as to the relative amount of labor required for wet and dry cleaning. Aqua Clean manufacturers, while acknowledging that pressing wet cleaned clothes may take longer, feel that the total labor required for cleaning will be comparable because spotters do not need to treat water-based stains.[13] EPA found that there was no appreciable difference in pressing times between dry cleaning and wet cleaning. This occurred in part because the demonstration facility hung garments to dry, which helped to reshape garments and remove excessive wrinkling, thereby lessening pressing requirements.[14] Similarly, managers at Ecomat feel that when wet cleaning pressers ore properly trained pressing rates of wet and dry cleaners should be comparable.[15] In this regard, it may be that installation of a wet cleaning machine may involve an investment in training for wet cleaning employees. This will act to increase the up-front capital expenditure necessary for a cleaner to set up a wet cleaning system, but will increase worker productivity and may increase long-term profitability.

Environment Canada recognized the importance of analyzing and comparing the labor requirements of wet and dry cleaning. While Environment Canada is currently working to complete and publish a numerical analysis of the labor requirements of wet cleaning, their preliminary finding is that pressing rates will not be significantly higher for a wet cleaner who carefully dries their clothes to avoid over-drying (over-drying can lead to excessive wrinkling of the clothes, which subsequently requires more labor to press). However, Environment Canada also found that pressing rates varied for different fabrics and types of garments. For some garments, pressing times of one and a half to two times the pressing rate of dry cleaning could occur, but for other garments pressing was similar or possibly slightly less than dry cleaning.[16] Similarly, a dry cleaner experimenting with wet cleaning in California found that pressing rates were, on average, 20–50 percent higher for wet cleaning.[17]

Some dry cleaners believe that pressing time for wet cleaning will be significantly greater than that of dry cleaning. For example, Bill Seitz, Executive Director of the Neighborhood Cleaners Association, believes pressing wet cleaned clothes could take two to five times longer than pressing dry cleaned clothes.[18] Our analysis was based on the assumption that a wet clean presser could process nine garments per hour at a wage of $9 per hour. Similarly, our analysis assumed that a dry clean presser could process 12 garments per hour at a wage of $9 per hour. That is, we assume that dry cleaners can press clothes at a rate 33 percent faster than wet cleaners, a range consistent with preliminary finding discussed above. The chart below details how changing assumptions about the pressing rates for wet cleaning would change the analysis. The base case of 9 garments per hour assumed in this analysis is shown in bold. (Note: dry cleaning pressing is assumed to remain at 12 garments per hour).

TABLE 14 - PRESSING RATE SENSITIVITY ANALYSIS

Pressing Rate for Wet Cleaner	Dry Cleaning Labor Costs	Wet Cleaning Labor Costs	Total Costs Dry Cleaner	Total Costs Wet Cleaner	Which System is More Profitable?
3 garments/hr.	$27,197	$108,787	$242,093	$325,398	Dry - $83,305
4 garments/hr.	27,197	81,590	242,093	293,714	Dry - 51,621
5 garments/hr.	27,197	65,272	242,093	274,703	Dry - 32,610
6 garments/hr.	27,197	54,393	242,093	262,030	Dry - 19,937
7 garments/hr.	27,197	46,623	242,093	252,977	Dry - 10,884
8 garments/hr.	27,197	40,795	242,093	246,188	Dry - 4,095
9 garments/hr.	**27,197**	**36,262**	**242,093**	**240,907**	**Wet - 1,186**
10 garments/hr.	27,197	32,636	242,093	236,682	Wet - 5,411
11 garments/hr.	27,197	29,669	242,093	233,226	Wet - 8,867
12 garments/hr.	27,197	27,197	242,093	230,346	Wet - 11,747

The point to note is the importance of assumptions about how many garments can be pressed per hour. As assumptions change, the difference in labor costs between wet and dry cleaning varies greatly. For example, if wet cleaning processing can be done at the same rate as dry cleaning processing, the wet cleaner will be $11,747 dollars more profitable than the dry cleaner. If more labor-intensive assumptions about pressing rates for wet cleaning are true, wet cleaning becomes relatively less profitable than wet cleaning. For example, at half the pressing rate of dry cleaning (six garments per hour), the wet cleaner will earn almost $20,000 dollars less than the dry cleaner. These figures show the overall importance of labor costs to assessing the economic viability of wet cleaning. In order for the economic viability of wet cleaning to be conclusively proven, better data regarding labor costs will be required.

Perc Mileage

A number of sources have cited that high perc mileage is now possible with advanced equipment. For example, an advertisement by the DynaClean solvent distillation system claims that usage rates as high as 1,800 pounds of clothes cleaned per gallon of perc can be achieved. This would amount to just under 100,000 pounds of clothes cleaned by a 55-gallon drum of perc. (See Section I: Inventory Analysis for further discussion of perc mileage.)

Table 15 depicts the annual cost of perc usage based on varying assumptions about the mileage of perc achieved by the dry cleaning machine. The base case, assumed in the analysis, is that a 55-gallon drum of perc can be used to clean 30,000 lbs. of clothes. The last column of the chart shows how differing assumptions about perc mileage would affect the total costs of the model dry cleaning facility. The table assumes that no additional capital costs are needed to achieve mileage rates above the 30,000 lbs. of clothes assumed in this report. Costs saving for perc disposal were estimated using the base case where still bottom disposal costs $841 per year. If perc mileage was doubled, it was assumed that perc disposal costs would be cut in half. Disposal of filters and separator water was assumed constant regardless of perc mileage. The fourth column describes how varying assumptions about mileage affect the estimate of which method, wet cleaning or dry cleaning, is more profitable. Note that if perc mileage is assumed at 85,000 pounds of clothes or above, dry cleaning will become more profitable.

TABLE 15 - PERC MILEAGE SENSITIVITY ANALYSIS

Perc Mileage[19]	Cost of Perc Use ($ per year)	Cost of Perc Disposal ($ per year)	Which System Is More Profitable	
20,000	1,143	1,121	Wet	+1,691
25,000	915	981	Wet	+1,323
30,000	**762**	**841**	**Wet**	**+1,030**
35,000	653	721	Wet	+801
40,000	572	631	Wet	+629
45,000	508	561	Wet	+496
50,000	457	505	Wet	+389
55,000	416	459	Wet	+301
60,000	381	421	Wet	+228
65,000	352	388	Wet	+167
70,000	327	360	Wet	+114
75,000	305	336	Wet	+68
80,000	286	315	Wet	+28
85,000	269	297	Dry	+7
90,000	254	280	Dry	+39
95,000	241	267	Dry	+67
100,000	229	252	Dry	+92

The baseline case, where perc mileage is assumed to be 30,000 lbs. of clothes cleaned per 55-gallon drum of perc, is shown in bold. Note that $1,122 dollars could be saved in perc purchase and disposal costs if perc mileage is increased from 30,000 lbs. up to 100,000 lbs. per drum. However, an inefficient machine getting only 20,000 lbs. per drum would drive up costs an additional $661 over the baseline. Thus, assumptions about perc mileage can affect the profitability of a dry cleaner by several hundred dollars. However, assumptions about perc mileage are not nearly as critical as assumptions about labor rates in affecting the profitability of a cleaning technology.

Liability Costs

The use of perc as a solvent exposes the owner of the dry cleaning shop to certain legal and financial liabilities not included in the model facility analysis. For example, the liability associated with small perc spills can severely harm an owner's prospects for selling property where a dry cleaner once operated. In this sense, the property value is depreciated by use of perc. Owners may also be liable for cleanup of contaminated soils and groundwater. In Florida, a surcharge of approximately $5 per gallon on perc helps to finance an insurance fund to pay for liabilities associated with spills of perc during transport. This would significantly increase solvent costs for the average dry cleaner. For example, adding this surcharge to the $5.20 assumed per-gallon price of perc would raise the annual cost of perc use in the model dry cleaning facility from $762 to $1,495.

Compliance Costs

An additional cost of perc usage, not considered in this analysis, is compliance with regulations regarding perc. These costs include filling out paperwork, monitoring indoor air quality, and installing additional pollution control equipment. It should be noted, however, that this analysis does include the cost of purchasing pollution control equipment ($1,183 per year), operating pollution control equipment ($383 per year in electricity costs), and disposing of perc as a hazardous waste ($3,575 per year).

Goodwill and Employee Morale

Potential but unquantifiable benefits of converting to wet cleaning include goodwill within the community and boosting employee morale. By decreasing the risks associated with perc use, a professional cleaner may improve the image of the shop within the community. This may help profitability by improving relations with neighbors, customers, fellow business people, and government officials. Similarly, if employees perceive reduced risk associated with their job, morale and job satisfaction may increase. This could result in increased productivity as well as decreased employee turnover rate, both of which would increase profits for the owner of a wet cleaning shop.

Water Use

The Aqua Clean washing machine includes a tank that can hold roughly 40 gallons of liquid. The machine can thus be modified so that water used in the last rinse cycle can be extracted from the wheel of the machine and stored in the tank. It is estimated that roughly 25 gallons of water could be extracted, which could then be reused during the first soak cycle of the subsequent wash load. In this manner, the water requirement of the Aqua Clean washer could be reduced from 100 gallons per load to 75 gallons per load. This would reduce annual water consumption from 208,000 gallons per year to 156,000 gallons per year, conserving 52,000 gallons of water per year. The net savings of this water reuse would be roughly $1,360 per year.

Leather and Suede Cleaning

Wet machines may allow a cleaner to expand the types of garment that they can clean. For example, most dry cleaners do not clean leather and suede garments on-site, because perc stiffens these fabrics and can cause their coloring to fade. Instead, dry cleaners typically send leather and suede garments to a specialist for cleaning. However, the owner of a wet machine may be able to clean these garments on site. For example, leather and suede can be cleaned in a wet machine using the normal detergents and a specially designed finishing agent, such as Aqua Clean's Suedesoft, that restores the oils and suppleness to the fabrics. By cleaning such garments on-site, instead of paying a specialist to clean them, a wet cleaner should be able to increase their profitability. Additionally, wet cleaners may be able to generate revenue by cleaning leather and suede garment received from other local dry cleaners who do not have wet machines.

Areas for Further Study

Labor Costs

The results of the model facility analysis demonstrate that wet cleaning can be economically competitive with dry cleaning. However, the analysis does not conclusively demonstrate which system is preferable from an economic point of view. Much will depend on local conditions. For example, water and perc prices (including taxes and surcharges) can vary dramatically from location to location. More importantly, further data is needed so that a more conclusive economic analysis can be completed. The most important area requiring further study is in the labor requirements of both wet and dry cleaning. As we have seen, assumptions about labor input are extremely important in assessing the economic viability of wet cleaning. Some suggest that pressing time for wet cleaning is several times greater, which would make the cost of wet cleaning significantly higher than estimated in this report. Then again, proper training may equalize the labor requirements for wet and dry cleaning. In any case the relationship between training and worker productivityneeds further study. Specifically, how productive is an untrained wet cleaner? How much would it cost a wet cleaning facitlity owner to increase the productivity of spotting and pressing staff? By better understanding these relationships, a more conclusive economic analysis could be completed. Until these uncertainties are resolved, cleaners are likely to continue their reliance upon the better understood practice of dry cleaning.

Evaluating Wet Cleaning Technologies

Another area worthy of further study is a comparative analysis of different wet cleaning machines. Environment Canada has already started demonstration projects involving a Unimac washer with microcomputer control and a more sophisticated Ipso Cleanwash System washer. Environment Canada is also setting up an additional demonstration project based on the Aqua Clean System. We chose the Aqua Clean System for this analysis because it is a state-of-the-art wet cleaning machine. As its name implies, the Aqua Clean System is a whole "system" involving a specific washer, dryer, and set of cleaning agents. The Aqua Clean dryer, in particular, is more sophisticated than those used with the Unimac and Ipso machines because it is the only dryer that directly measures residual moisture in the clothes. For example, the American dryer used with the Ipso washing machine does not directly measure residual moisture; instead it uses temperature control to estimate residual moisture. Not surprisingly, the more advanced Aqua Clean washer and dryer are also more expensive than their counterparts. For example, the Ipso washing machine and American dryer only cost about $10,000 and $3,000 respectively.[20] It is important to understand how investing capital in more advanced wet cleaning equipment affects performance. Future studies of wet cleaning need to analyze the levels of performance that are achieved by different types of wet cleaning machines. Results will give cleaners the information necessary to choose between the various wet clean machines on the market today.

Volume

One concern expressed by several reviewers is that wet cleaning may only be efficient for a store that receives a certain volume of incoming clothes. Loads washed in a wet clean machine must be of a similar color and fabric type. If wet cleaners do not receive enough clothes of a certain color and fabric type, then they will have to run inefficiently small loads in order to promptly clean and return the clothes to the customer. Further studies should examine the optimal range of clothes volume that can be efficiently processed by various size wet cleaning and mixed facilities.

Drip Drying

Several reviewers noted that drip drying clothes may involve additional costs not included in this study. For example, Ecomat is concerned that drip drying certain garments may cause those garments to smell unfresh. To ensure garments are fresh smelling and acceptable to customers, Ecomat dries garments in specially designed cedar closets. However, this may involve a start up cost to build the closet as well as requiring the cleaner to lease a larger store, which increases rent. Additionally, drip drying requires more time input by employees to individually hang items. Finally, drip drying generally slows the cleaning process, increasing the amount of time it takes to provide cleaning services. This increase in service time may be undesirable from a consumer standpoint, which may potentially impact the wet cleaner's profitability. For purposes of this study, all items were assumed to be dried in the Aqua Clean dryer. However, a more comprehensive economic analysis would take into account that some clothes may be drip dried, incurring additional costs to the cleaner.

Other Areas for Further Study

Other important areas where better quantification of input costs would be helpful in comparing wet cleaning with dry cleaning include:

- Other energy costs (fuel for steam generation, electricity not related to cleaning and drying, etc.),
- Cost of spotting chemical use,
- Expected life and maintenance of wet clean machines,
- Cost of water, including the potential savings that could be achieved by recycling water used in the last wash cycle.

Final Remarks

It is important to realize that this new wet cleaning process is an emerging technology. It is quite possible that further improvements in wet cleaning technology will increase performance and/or lower costs. As more manufactures enter the market to sell wet cleaning machines, dryers, and detergents, competition may drive down prices. For a product such as wet cleaning detergent, prices may fall over time as the market for this good grows and suppliers are able to take advantages of economies-of-scale in production. It is also important to consider that increasing hazardous waste disposal costs, as well as additional regulating of perc-based machinery, could drive up the cost of dry cleaning. Therefore, a professional clothes cleaner choosing between wet and dry cleaning must analyze the current costs involved in each technology and anticipate how costs may change in the future. In this regard, wet machine cleaning certainly deserves increased consideration by professional cleaners. However, as this analysis has shown, uncertainties over the labor required to run a wet cleaning shop are critical to assumption about the profitability of switching to wet cleaning. Under certain assumptions about labor rates, dry cleaning is more profitable than wet cleaning and, under the most pessimistic assumption about labor rates, wet cleaning may fail to even earn a profit. Until more conclusive studies of labor requirements are completed, cleaners are likely to continue their reliance upon the known profitability of using traditional dry cleaning.

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[1]A wet cleaner located in New York, New York.
[2]Prices from Darien Fabricare, a dry cleaner in Darien, Connecticut. (Personal communication with Mike Astorino, Darien Fabricare, February 4, 1995.)
[3]This item costs extra, depending on the fabric.
[4]U.S. EPA, *Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process*, EPA 744 R-93-004 (1993). Item #44 in the Model Cleaning Facility Profile; Line By Line Description and Sources.
[5]U.S. EPA 1993, p. 3-2.
[6]Ibid.
[7]U.S. EPA 1993, Appendix IV.1; Model Cleaning Facility Design Parameters.
[8]Ibid.
[9]Personal communication with Kevin Daly, Product Manager, Aqua Clean Systems, Inc., January 31, 1995.
[10]U.S. EPA 1993, Appendix IV. 2; Model Cleaning Facility Profile; Line by Line Description and Sources, item #3.
[11]Daly 1995.
[12]U.S. EPA 1993, p. 3-4.
[13]Daly 1995.
[14]U.S. EPA 1993, p. 2-15.
[15]Personal communication with Diane Weiser, CEO and President, EcoFranchising, Inc., January 1995.
[16]Personal communication with Toby Brodkorb, Green Clean staff engineer, Environment Canada, March 30, 1995.
[17]Personal communication with Steve Fazio, President, Flair, Inc., March 31, 1995.
[18]Personal communication with William Seitz, Executive Director, Neighborhood Cleaners Association, January 3, 1995.
[19]Perc milage is measured as pounds of clothes cleaned per 55-gallon drum of perc.
[20]Brodkorb 1994.

V. REGULATORY ASSESSMENT

In doing a comparative analysis of traditional perc dry cleaning and wet cleaning, it is useful to outline the statutes and regulations pertaining to both methods. These regulations can affect cost, equipment requirements, cleaning processes, overhead, liability to the dry cleaner, investments, and the amount of time a cleaner spends learning the laws – all of which ultimately affect profits. The traditional perc dry cleaner must comply with significantly more regulations than a wet cleaner because perchloroethylene is listed as hazardous under the Occupational Safety and Health Act (OSHA), the Clean Air Act (CAA), the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Since many states have their own regulations which either meet or exceed federal regulations, this analysis will focus on the federal regulations which are the minimum standards for compliance. Each of the major federal statutes and associated federal regulations which affect a commercial cleaning business is described below.

OSHA Regulatory Requirements

The Occupational Safety and Health Act of 1970 was passed to protect the workplace environment. It is administered by the Occupational Safety and Health Administration which sets industry standards, such as Permissible Exposure Levels (PELs), and a wide range of specific health and safety standards, focusing on workplace conditions.

On January 19, 1989, OSHA reduced the permissible exposure level for perc from 100 parts per million (ppm) to 25 ppm.[1] The reduction was part of a larger effort by OSHA to update a total of 428 PELs that had been based on Threshold Limit Values (TLVs) set in the 1960s and adopted by OSHA when it first began in 1970.[2] The TLVs were based on recommendations of industry and government scientists working for the American Conference of Governmental Industrial Hygienists (ACGIH). According to the ACGIH, TLVs are "health-based recommendations derived from assessment of the available published scientific information from studies in exposed humans and from studies in experimental animals."[3] While TLVs were intended to be set at levels that would prevent health effects, in many cases they have been set at levels at which disease is known to occur in humans.[4] Nonetheless, OSHA used the Threshold Limit Values set by the ACGIH as a basis for setting Permissible Exposure Levels.

The new standard limited the Total Weighted Average (TWA) of perc releases into the air (within the workplace) to a maximum of 25 ppm during an eight-hour period.[5] The regulation would have gone into effect on December 31, 1991, and dry cleaners had until December 31, 1993 to meet the standard. However, soon after the PELs were issued, a suit was filed by industry groups to contest the procedure used by OSHA to change the 428 PELs at once. In July 1992, an appeals court vacated the 1989 OSHA standard revising the PELs for perc[6] and 427 other substances. By that time, many dry cleaners and state OSHA agencies had already begun making changes to meet the 25 ppm PEL. Many dry cleaners acted to meet the PEL by installing control devices such as carbon adsorbers or refrigerated condensers and implementing work practice controls. Today, OSHA recommends that dry cleaners limit indoor air emissions of perc to 25 ppm, but can only enforce the old PEL of 100 ppm TWA of perc.

1990 Clean Air Act Amendments (CAAA)

The Clean Air Act was passed in 1970 and was significantly amended in 1977 and 1990. Its purpose is to regulate ambient air emissions, meaning pollutants emitted to the outside atmosphere. Section 112 of the Clean Air Act regulates hazardous air pollutants and is particularly relevant to dry cleaners. Prior to the 1990 CAAA, the standards for hazardous air pollutants were primarily harm-based. This means that there were uniform national standards for acceptable emission levels of hazardous pollutants from given categories of stationary sources. The harm-based standards did not take into consideration local conditions, specifically the concentration of hazardous air pollutants in certain highly industrialized areas. Regulators felt the harm-based standards were not protecting air quality because they set limits for the amount of pollution that could be emitted from sources, instead of setting levels so that would protect air quality in a particular geographic area.[7]

In 1990, Congress amended the Clean Air Act (CAA) and shifted to a technology-based strategy for regulating hazardous air pollutants. The legislation specifically identified 189 toxic air pollutants, including perc, which would be regulated under Section 112.[8, 9] This section of the CAAA specifies that emissions of one or more of these chemicals must be controlled using Maximum Achievable Control Technology (MACT).[10] Congress charged the U.S. EPA with writing the regulations for implementing the CAAA. In December 1991, U.S. EPA proposed National Emission Standards for Hazardous Air Pollutants (NESHAP) regulating the dry cleaning industry's emissions of perchloroethylene. These regulations went into effect in September 1993, were amended on December 20, 1993, and are to be fully implemented by September 23, 1996.[11]

NESHAP Overview

"NESHAP calls for better work practices and record keeping, a fugitive emissions prevention program, regular filter changes and checks for leaks."[12] In order to reduce fugitive emissions, NESHAPs set out a range of technology requirements. It appears that the U.S. EPA was trying to require technology that would limit perc air emissions but not penalize dry cleaners who had just purchased emissions control equipment prior to the passage of the law. As a result, the rule is not as strict as some emission control experts believe it should be and allows transfer machines, retrofitted vented machines, and carbon adsorbers to remain in use for certain cleaners.[x] See Appendix E for a table which details the regulatory specifications. While these technologies do reduce perc air emissions, they are not the Maximum Achievable Control Technology required under the Clean Air Act Amendments. (MACT is a closed-loop, dry-to-dry machine with a refrigerated condenser.)

Another example of how NESHAP allows variances from MACT pertains to vapor recovery systems. There are two types of vapor recovery systems to catch perc residues in the air emissions that are circulated during the drying phase of the cleaning process.

- Refrigerated condensers remove the vaporized perchloroethylene from the air by turning it back into a liquid, which is then reused in the cleaning cycle.
- Carbon adsorbers operate by adsorbing perc to the surface of a bed of activated carbon.

Perc is recovered by steam stripping the carbon bed and then distilling the water/perc mixture. Both carbon adsorbers and refrigerated condensers can reduce air emissions in dry-to-dry machines by 95 percent if the carbon adsorbers are maintained properly and stripped of perc as directed by the manufacturer.[13,y] However, refrigerated condensers create 30 times less perc-contaminated wastewater than carbon adsorbers. Because contaminated wastewater can be a major source of liability for dry cleaners, there was preference to have the NESHAP require refrigerated condensers over carbon adsorbers.[14] A strict requirement of the refrigerated condensers would put undue financial burden on

[x]Comments received on a draft of this document indicated the dry cleaning industry wanted the NESHAP to phase out transfer machines but the EPA did not require it to do so in the final rule. (Sources include Janet Hickman, Dow Chemical; and Katy Wolf, Institute for Research and Technical Assistance.)
[y]Carbon adsorbers will only meet this efficiency level if the machine operator is diligent in strip cleaning the adsorber on a regular maintenance schedule. Technology control experts acknowledge that this is not often the case, resulting in less than optimal perc removal.

cleaners who had just purchased carbon adsorbers, so the rule for existing facilities (those in place prior to December 9, 1991) was written to allow either device.

NESHAP is very specific about which emission control technologies meet the MACT standard, but the requirements differ depending on whether the facility being regulated is new or existing, whether it is classified as a small, large, or major perc user, and which type of equipment is in place (transfer or dry-to-dry). The three tables below summarize NESHAP's definitions of categories based on equipment, amount of perc used per year, and type of equipment used.

TABLE 16 - EQUIPMENT DEFINITIONS UNDER NESHAP

"Existing" equipment	installed before December 9, 1991 (date the regulation was passed)
"New" equipment*	installed on or after December 9, 1991 (date the regulation was passed) and before September 22, 1993 (date the regulation was implemented)
"New" equipment*	installed after September 22, 1993

*There are two different "new" categories depending on the date of installation.

TABLE 17 - SOURCE DEFINITIONS UNDER NESHAP

The regulations are further specified based on the amount of perc purchased per year.

Major source	purchased more than 2,100 gallons per year
Large source	purchased between 140 – 2,100 gallons per year
Small source	purchased less than 140 gallons per year

TABLE 18 - TYPES OF DRY CLEANING EQUIPMENT

Transfer	one cleaning machine, a separate dryer
Dry-to-dry	cleaning and drying done in same machine

(See Appendix E for a chart detailing the NESHAP requirements.)

The next section gives merely an overview of these very detailed regulations as they apply to "large dry-to-dry" facilities which have similar characteristics to the model facility under analysis in this study. The level of detail in the regulations is much more rigorous than described here and one should refer to the aforementioned NESHAP chart in Appendix E for specifics.

NESHAP: "Large" Facilities

• For Machines Installed Prior to December 9, 1991

Dry cleaners who had purchased their dry-to-dry machines prior to December 9, 1991 have until September 23, 1996 to install emission controls. If they had installed a carbon adsorber prior to September 22, 1993 then the carbon adsorber would meet the emission control requirement. If they had not installed a carbon adsorber by September 22, 1993 then they have until September 23, 1996 to install a refrigerated condenser.

• For Machines Installed between December 9, 1991 and September 22, 1993

By September 22, 1996, machines purchased in this time period must be fitted with a refrigerated condenser to meet the NESHAP. If these large facilities already had a carbon adsorber installed prior to September 22, 1993, then they could temporarily meet the NESHAP requirement with the carbon adsorber but would have to switch to a refrigerated condenser by September 22, 1996.

• For Machines Installed after September 22, 1993

After September 22, 1993 only dry-to-dry machines can be installed and they must be equipped with a refrigerated condenser. Carbon adsorbers cannot be used to meet the NESHAP requirement for machines in this category.

Record-keeping, Reporting, Monitoring, and Inspections

Enforcement of NESHAP is primarily through record-keeping, reporting, monitoring, and self-inspections, because of the fragmented nature of the industry and the lack of enforcement personnel in the EPA. Under the new regulations, dry cleaners must keep track of their perc purchases and maintain a running record of their annual consumption. At the beginning of each month, they have to total up the purchases made during the previous 12 months. They need to keep these records on file for a minimum of five years. They must also carry out weekly inspections to make sure that equipment is not leaking, either liquid or vapor. Dry cleaners that use fewer than 140 gallons of perc per year, "small" operators, only have to conduct inspections every two weeks.

Under the new NESHAP, dry cleaners are required to file several different reports indicating whether they operate transfer or dry-to-dry machines, whether they are a new or existing facility, and whether they are a small, large, or major source of perc consumption.[15] The performance of emission control equipment, such as add-on refrigeration units or add-on carbon adsorbers, must also be reported.[16] Filters must be drained either in their housing or in sealed containers for a minimum of 24 hours before disposal.[17]

Repairs

NESHAP specifies that if any leaks are found, repairs must be made within 24 hours, or if replacement parts need to be ordered, orders must be placed within two working days and repairs must be made within five days of receiving the parts. The results of all inspections and corrective actions must be recorded and the records kept for five years.[18]

NESHAP Requirements and the 1996 CFC Phase-Out

In an effort to limit emissions from perc dry cleaning machines, the Clean Air Act Amendments required use of Maximum Achievable Control Technology. The refrigerated condenser is currently the best emission control technology available. Large dry cleaners are required under NESHAP to install this technology by September 22, 1996 at the latest, but some cleaners were required to install condensers by September 22, 1993. However, CFCs are present in most of the refrigerated condensers currently being used to recover perc from air emissions. CFCs will be phased out under the Clean Air Act by January 1, 1996. The CFC ban may cause additional cost and confusion to dry cleaners trying to comply with the NESHAP regulations. On the one hand, they need a refrigerated condenser to reduce hazardous air emissions, and on the other hand, the device they are being required to use to control emissions is coming under regulation through a different law. To comply with the CFC ban, dry cleaners will have to make some adjustments to their refrigerated condensers so they can substitute alternative coolants for freon.

Resource Conservation and Recovery Act (RCRA)

RCRA is a waste management statute that regulates how solid and hazardous waste should be handled and disposed of to ensure human health and environmental safety. The regulations institute a tracking system that follows the transportation and disposal of hazardous waste from the time of its generation to its final use. This is known as a "cradle to grave" regulation. RCRA also authorizes the EPA to engage in corrective action that can remedy problems and to impose penalties for non-compliance.

The use, storage, and disposal of perc is regulated under RCRA's 1984 amendments. "The 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA required the EPA to phase out the land disposal of untreated hazardous wastes by 1992 at the latest. The halogenated solvents were restricted from land disposal on November 8, 1986."[19] "The regulation prohibits the land disposal of wastes containing more than one percent or 10,000 ppm by weight of solvent. As a result, spent solvent from dry cleaning operations and the still bottoms from the recovery of the solvent used in dry cleaning operations must be treated and cannot be land disposed."[20] However, EPA excluded many dry cleaners from complying with this rule by designating a category called conditionally exempt small quantity generators (CESQG).[21] This exemption is for businesses that produce less than 100 kg., or 220 lbs., of hazardous waste per month.

In order to comply with RCRA, dry cleaners have to pay a service to remove the hazardous waste. These services are either municipal or commercial waste haulers licensed to transport and dispose of hazardous waste. Cleaners which qualify as small quantity generators must ensure that the waste is disposed of by a facility which meets one of five conditions such as being permitted or authorized to handle hazardous waste.[22] To avoid liability, it is recommended that cleaners get letters back from the haulers acknowledging that they have in fact notified the haulers and landfill operators that it was hazardous waste.[23] Cleaners which do not meet the RCRA small quantity generator exemption pay hazardous waste disposal services, such as Safety-Kleen to remove the waste. These companies extract additional perc from the muck waste and resell it to brokers. The perc-laden waste that cannot be recycled is sold to cement kilns which incinerate it. For a detailed discussion of Safety-Kleen's breakdown of markets for recycled perc, refer to the section in this report on environmental impacts.

Solid Hazardous Waste

While much of the perc used in a dry-to-dry machine is filtered and recycled, solid hazardous waste is generated from several sources. Still bottoms are the residues from the perc distillation process and contain up to 50 percent perc in addition to non-volatile residues (i.e., detergent, waxes, oils and greases.)[24] Filters catch solids, such as hair and soil particles, and are used to filter the solvent so it can be reused. The perc-laden muck from the filters is cooked in muck cookers to condense and reclaim as much solvent as possible. However, the muck contains a significant level of solvent even after going through the cooker, so hazardous waste disposal is still required under RCRA. Filters, such as carbon-core cartridges, powder, disc, and polishing units also have to be disposed of as hazardous waste when they are spent. The drums in which virgin perc is delivered can be used to store hazardous wastes, such as still bottoms and muck. "Improper management of drums can lead to costly fines and unnecessary spills and leaks. Under RCRA, generators must weekly inspect hazardous waste storage areas for spills and leaks."[25] However, there are no RCRA inspectors doing this job, just the cleaners themselves. The waste is disposed of as described above.

Hazardous Wastewater

Water used in the dry cleaning process becomes contaminated with perc. The total amount of wastewater generated in a dry cleaning facility will depend on the equipment used. Steam used during the spotting process adds some water to a garment and a small amount of water is mixed with perc in the wash cycle to remove water-soluble soils. The majority of the water used in dry cleaning is associated with the use and maintenance of emission control devices and perc filtration devices. These include carbon adsorbers, cartridge stripping cabinets, stills, muck cookers, and refrigerated condensers.[26] After water passes through these devices, it contains perc. Most of the perc is removed from water through two processes: first distillation and then gravity separation in a water separator. Even after these two steps, a small amount of perc remains in the separator water. Usually, concentrations of approximately 150 ppm of perc are found in separator water because perc's water solubility at 25 degrees Celsius, the average temperature of water used to strip carbon adsorbers, is 150 ppm. The solubility of perc decreases as water temperature decreases so with an increased use in refrigerated condensers, which cool the wastewater, the amount of perc remaining in separator water has been found to be as low as 25 ppm.[27] Refrigerated condensers produce approximately 50 gallons per year of perc-contaminated separator water, and carbon adsorbers produce about 1500 gallons per year.[28]

RCRA classifies slightly contaminated wastewater which is generated by dry cleaners from various sources as an FOO2 category hazardous waste. The toxicity characteristic leaching procedure (TC) cutoff for perc is very low – at 0.7 ppm. The separator water, which contains about 150 ppm, is therefore hazardous waste because it exceeds the TC level.[29] Historically dry cleaners have poured separator water down the drain. It is unclear as to whether or not this is illegal under RCRA because of an exemption.[z] EPA exempts wastewater that is going to a Publicly-Owned Treatment Work (POTW) from RCRA because the minute the wastewater goes down the drain it could be regulated by POTWs under the Clean Water Act, and EPA wanted to avoid regulating a chemical under two laws simultaneously. The exclusion produces a gray area in terms of interpreting the RCRA rule on wastewater. While the water is at a dry cleaning facility, it is regulated by RCRA as a hazardous waste, meaning that a dry cleaner would have to get a permit from a POTW in order to dispose of the separator water legally or pay to have it disposed of by a service. However, the minute the wastewater is poured down the drain, a RCRA exclusion goes into effect, and unless POTWs require local permits, it is not illegal to dispose of the wastewater in that manner.

POTWs vary in the allowable amounts of perc they will accept in wastewater.[30] The amount of wastewater being discharged to sewers relative to industrial laundries or plating facilities is so small that most POTWs do not bother requiring permits. (See section on state regulations for a discussion of a Los Angeles County POTW which is now requiring permits for wastewater discharge.) Technically, dry cleaners are required to notify their POTW of the type, volume and concentration of hazardous wastewater they produce. But since separator water has not been of great concern to POTWs from a treatment viewpoint, they often do not enforce the notification requirement. Now that it is of concern from a liability viewpoint, POTWs are paying closer attention to the dry cleaning industry. Dry cleaning industry associations no longer recommend sewer discharge of separator water[31] because the problem of perc leaking from sewers has increased the risk of liability under CERCLA as discussed in the next section. One certain way that a dry cleaner can legally dispose of separator water is to pay to have it disposed of off-site as hazardous waste.[32]

Another technology for getting rid of wastewater is a separator water evaporator. This technology can be problematic though, depending on local laws and permit requirements. Technically, separator water evaporators are considered wastewater treatment units under RCRA. The EPA ruled that dry cleaners using evaporators are not required to have permits to run the evaporators, but some air quality management districts, such as the South Coast Air Quality Management District in Los Angeles, are going to require that evaporators be certified by 1996. While evaporators solve the problem of contaminated wastewater causing groundwater and soil pollution, some states are considering them problematic from an air quality point of view.

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[z]If wastewater is discharged to a sewer system, mixes with sewage, and goes to a POTW, it is exempt from RCRA. (40 CFR Section 261.4 paragraph A1, as per a conversation with a technical assistant on the RCRA Hotline).

Comprehensive Environmental Response, Compensation, & Liability Act (CERCLA)
[Also known as Superfund & the 1986 Superfund Amendment & Reauthorization Act]

Superfund is a liability statute that holds all potentially responsible parties (PRPs) liable for the release of hazardous waste. A PRP is defined as a past or current owner or operator of a waste site, a generator of the waste, or a transporter or arranger of transport of the waste. CERCLA has joint and several liability, strict liability, and retroactive liability. Joint and several liability means that all of the above named parties can be held collectively responsible for the cost of cleanup regardless of the extent of their involvement. Strict liability means that the PRPs will be held liable under the law regardless of lack of intent or negligence. The EPA does not have to prove negligence, nuisance, or intent on the part of the PRP in order to have them pay for the cleanup. Strict liability often applies to cases involving hazardous substances, and there are very few defenses for this cause of action. Retroactive liability means that PRPs can be held liable for releases of hazardous waste regardless of whether or not the disposal methods used were legal at the time of the release.[33] If a cleaner released hazardous chemicals (i.e., poured perc down the drain) in the past, and if that release resulted in toxic contamination today, even if it were not illegal at that time to dispose of hazardous chemicals in that manner, retroactive liability would hold the cleaner liable for cleanup costs. CERCLA liability has serious implications for perc dry cleaners.

Historically, dry cleaners have poured perc-contaminated separator water down the sewer. Regular use of perc in daily operations can also lead to accidental spills and leaks of perc onto cement floors. Perc-laden separator water can contaminate groundwater and soil by permeating concrete or seeping through cracks in sewers. "In recent years, it has been shown that this practice has caused soil and groundwater contamination at many dry cleaning sites."[34] "The effluent water stream may contain up to 150 ppm perc and contribute as much as 1.9 pounds per year of perc loss from a carbon adsorber controlled machine."[35] This small wastewater stream is discharged to the municipal sewer by more than 50 percent of dry cleaners. "While this loss is very small in total volume terms, leakage from the sanitary sewer can result in contamination of groundwater."[36]

As previously mentioned, the dry cleaning industry recommends switching from carbon adsorbers to refrigerated condensers to reduce the amount of wastewater created. This switch can reduce wastewater volume by 30 times.[37] Industry also recommends that dry cleaners stop disposing of wastewater in the sewer.[38,aa] "Many dry cleaners have voluntarily discontinued this practice and the cleaning industry has sponsored legislation in several states and in Congress to develop clean-up programs for past contamination."[39]

Discharge of perc-bearing wastewater into the sewer by dry cleaners is being investigated as a most likely source of groundwater contamination in Sacramento, Modesto, Stockton and other cities in Central California by the Regional Water Quality Control Board."[40] CERCLA liability due to groundwater and soil contamination is one of the regulatory issues of greatest concern to dry cleaners today.[41]

Depending on the levels of perc present in the soil and groundwater around a dry cleaner, the property could be considered a liability should the current owners decide they want to sell the property. There is a clause in CERCLA that requires potential property purchasers to exercise due care in inspecting a site for potential hazardous substances prior to purchase. (If they do this, they would not be held liable under CERCLA should hazardous substances appear in the future.) Known as the "innocent landowner defense," it is one of the few defenses to CERCLA liability, and therefore the pre-purchase inspection is almost always performed prior to the purchase of a dry cleaning establishment.[42] Once an inspection is done, the report goes to the EPA, so any level of perc detected in the inspection is reported to the federal government. As of fiscal year 1993, the EPA's Records of Decision database showed perc contamination at 203 out of a total of 1302 sites on the Superfund National Priority List (NPL) since it began in 1981.[43] The way the current strict liability clause in CERCLA (Section 107) works is that any future buyers of the property (who are aware of its potential for perc contamination), as well as the current owners and possibly even creditors could be held liable for the cost of cleanup should the site be listed on the NPL. This means that it will be increasingly more difficult in the future to sell property that formerly hosted a dry cleaning facility.

Dry cleaners across the country are exposed to major liability for past perc disposal practices and are at risk of financial disaster due to liability for groundwater and soil contamination. In 1994, when CERCLA was up for reauthorization, dry cleaning industry associations submitted an amendment to CERCLA proposing the establishment of a dry cleaning industry-paid-for fund to be used for cleanup of contaminated sites not on the

[aa]Alternative ways to deal with the separator water, such as paying a service to dispose of it, or evaporating the perc and the water completely (which may also require permits in some states or sanitation districts) are discussed in the RCRA section of report.

NPL. "In the amendment, the industry (was) not seeking an exemption from Superfund, but instead the shifting of liability from a plant-by-plant basis to the industry as a whole, via the establishment of a National Dry cleaners Cleanup Fund."[44] However, the amendment died when concern was expressed in the Senate regarding the appearance of imposing a new "tax" on an industry. CERCLA was not reauthorized in 1994, and although the dry cleaning industry tried to be proactive and responsible for ensuring that funds would be available for cleanup, the federal regulations have not changed.

State Standards

States are required to adopt and enforce federal regulations, but they also have the right to adopt rules stricter than federal regulations and will do so if they deem it necessary. States have developed stricter regulations to address issues of particular concern to their state. In California, air quality issues and strong environmental regulations are of primary concern. In New York, mixed residential and commercial occupancy of buildings and potential health impacts on residents top the regulatory agenda. In Florida, the low water table and the potential for groundwater contamination are of prime importance. In Connecticut, concern over the potential loss of property value resulting from contamination and liability issues has inspired the dry cleaning industry to sponsor legislation for a state cleanup fund. Brief descriptions of some of these laws are given below to provide a glimpse of trends in state regulations.

California

The California Air Resources Board (CARB) listed perc as a toxic air pollutant and in Southern California, the South Coast Air Quality Management District (SCAQMD) has adopted a rule for controlling emissions from perc dry cleaning equipment. CARB's regulation, Airborne Toxic Control Measure for Emissions of Perchloroethylene From Dry Cleaning Operations, is much stronger than the EPA's NESHAP. The California regulation, which was implemented in 1994, bans all transfer machines and requires dry cleaners to use closed-loop dry-to-dry machines with refrigerated condensers. This rule also bans carbon adsorbers as the primary emissions control technology, but recommends it as a secondary control to be used in conjunction with a refrigerated condenser.

Perc is listed by the State of California as a known carcinogen. "Under the state's landmark toxic control law, passed by the voters in 1986 and commonly known as Proposition 65, any business that exposes people to a listed chemical must give clear and reasonable warning to the individuals exposed. In addition businesses may not discharge a listed chemical into any source or potential source of drinking water."[45]

The Orange County Sanitation Districts and the Los Angeles City Bureau of Sanitation recently passed a rule that drequires ry cleaners to get permits to release separator water to sewers or have zero discharge of perc to sewers. This requirement was spurred by a recent court ruling in Northern California in which a POTW was held liable as a PRP (in conjunction with past and present owners of a dry cleaning facility) for perc groundwater contamination.[46]

New York

The New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Health are concerned about indoor air emissions of perc and exposure to residents living in apartments located above and next to perc dry cleaning facilities. These two departments have entered into a Negotiated Rulemaking (Reg-Neg) with the dry cleaning industry, environmental and consumer groups, and unions to develop rules that will help to protect residents living above or near dry cleaning facilities, without putting dry cleaners out of business.[47] "To minimize transmission of solvent from the operation to residences, the NYSDEC regulations will impose the following requirements on mixed-use buildings: phaseout of transfer machines; addition of vapor barriers or room enclosure; and installation of room ventilation systems providing for a complete air exchange every 5 minutes."[48]

Florida and Connecticut

Florida and Connecticut are two examples of states where dry cleaners were so concerned about strict, retroactive, and joint and several liability that they lobbied to pass a state tax on dry cleaning to establish a fund to pay for future liability claims against dry cleaners. In Connecticut, it was the "very real fear that every dry cleaning plant in Connecticut ... would be worthless on the open market or as collateral for a loan"[49] that inspired Tim McCann, a dry cleaner in Middletown, CT, to initiate a statewide dry cleaning toxic clean-up bill. In Florida, dry cleaners now pay a 1.5 percent gross receipts tax on sales and a $5.00 per gallon tax on perc[50] as contributions to the state's retroactive liability fund. Floridians rely on a low groundwater table for their drinking water, and passed the tax to ensure their state would continue to have a safe, local source of drinking water.

The challenge posed by a state's ability to pass stricter laws is that while federal agencies set specific dates by which dry cleaners must reach full compliance with the federal regulations, there is no requirement that states finish imposing their regulations by the same deadline. Just as a dry cleaner comes into compliance with federal regulation, a more stringent state law could be passed requiring the dry cleaner to comply with another deadline and possibly update equipment just purchased to meet federal standards. This creates a climate of uncertainty for dry cleaners who need to invest in new pollution control technologies today in order to safely and legally use perc, but who don't know if stricter state standards will be passed in years to come. This uncertainty due to potential state regulations, combined with the anti-regulatory mood of Congress, is likely to discourage a dry cleaner from working on compliance until right before the deadline, just in case there are changes in the regulations

Wet Cleaning

Up to this point, the regulations researched for this analysis only affect the dry cleaning industry, not wet cleaning as defined in this paper. Of course there are standard labor and business laws that apply to any commercial cleaning business, such as child labor laws, zoning codes, etc. but these are not being addressed in this study since they impact wet and dry cleaning equally. According to Ecomat, a wet cleaner in New York City, there are no federal or state statutes specifically regulating the wet cleaning process.[51] This is because the wet cleaners under analysis use biodegradable detergents instead of perc, and nonchlorinated spotting agents which are not regulated under federal statutes as toxins. Therefore, wet cleaners do not have hazardous air emissions which would be regulated under OSHA and the CAAA, they do not produce hazardous waste which would be regulated under RCRA or by POTWs, and they do not have any major sources of liability under CERCLA.

One area of potential concern for wet cleaners is the wastewater they produce. The wet cleaning process produces wastewater at levels of quality and quantity currently acceptable to publicly owned treatment works (POTWs, local regulatory agencies that set standards for wastewater) in the areas where wet cleaning is currently operating.[52] However, if a dry cleaner converts to wet cleaning, there would be an increase in sewer usage that would be associated with an increase in monthly sewer service fees. A potential negative impact wet cleaning could have on POTWs would be to increase the amount of water going into the sewer system. This would only be an issue if a POTW were already near capacity.[53] However, volume of water could be an issue for POTWs in the future if the entire garment care industry switched to wet cleaning. To address this, wet cleaners are experimenting with on-site wastewater recycling programs.[54]

In terms of impacts on the quality of wastewater, as long as the detergents could biodegrade in their treatment facilities it would not be a problem.[55] POTWs presently treat domestic sewage that contains many different types of home laundry and dish detergents, not all of which are biodegradable. Since wet cleaning detergents are biodegradable and free of phosphates, they should pose no problems for POTWs which are designed to handle domestic sewage. Home laundry processes remove the same greases, oils and dirts from our clothes that would be removed at a wet cleaner. Therefore, we can assume that the domestic sewage contains the same greases, oils and dirts that would be in wastewater from a wet cleaner and should pose no additional problems to POTWs.

Care Labeling Requirements

The regulations discussed thus far deal with human health and environmental issues. In addition to these regulations, there is an additional regulation, the Care Labeling Rule, which does not directly regulate cleaners, but which strongly influences professional cleaning operations. Therefore, the Care Labeling Rule is of concern to both the dry and wet cleaning professions.

The Federal Trade Commission (FTC) has jurisdiction over the rule requiring textile manufacturers to state care instructions for textile wearing apparel and certain piece goods. The Care Labeling Rule (16 CFR Part 423, Section 6(b)) states that "...if either washing or dry cleaning can be used on the product, the label need have only one of these instructions."[56] Since "washing" is a very broad and an undefined category, whereas dry cleaning is well understood and generally a uniform process,[57] as a matter of convenience and to avoid ambiguity, textile manufacturers most often list "dry cleaning" as the method of care even though "washing" and "dry cleaning" may both be viable options.

The Care Labeling Rule does not legally bind dry cleaners to follow the care instructions on a garment.[58] However, for fear of damaging the garment, most cleaners refuse to process garments with a method other than that indicated on the care label. If a garment is damaged during professional cleaning, the customer expects the cleaner to compensate for the damage. Only if the damage occurs while following the care label instructions can a cleaner legally make a claim against the textile manufacturer. Since professional cleaners have much at risk (e.g., loss of customers, high reimbursement costs relative to total profits), they are extremely diligent in adhering to care label instructions. Therefore, professional cleaners will dry clean a garment if it is labeled dry clean only, even if they know it technically could be wet cleaned and would result in a better product if wet cleaned.

Furthermore, the Care Label Rule is not enforced and professional cleaners have little faith in the accuracy of care labels.[59] There are numerous examples of care labels which list care instructions other than the two approved categories. For example, the Neighborhood Cleaners Association recently found a label stating "dry clean with Arklune."[60] Not only is this label not approved by the FTC, the NCA has never heard of Arklune. The same care label also contradicted itself by carrying the symbol for all "methods of cleaning are acceptable" (a circled A). There are other examples of labels which state "do not dry clean" and "do not wash."[61] Since professional cleaners function in a litigious environment and there is little truth in care labeling, cleaners are forced to turn away garments when the cleaning instructions are ambiguous and poorly labeled.

In light of these issues, the Design for the Environment (DfE) project asked the FTC to revise the Care Label Rule. On June 15, 1994, the FTC requested public comment on the Rule. The DfE participants submitted comments stating that the Rule limits the options professional cleaners and customers have for cleaning their garments and should be strengthened with respect to wet cleaning.[62] The comment reads: "The United States Environmental Protection Agency's (EPA's) Dry Cleaning Project believes that FTC's Care Labeling Rule should be revised to require textile manufacturers to explicitly state whether a garment can be effectively cleaned by solvent-based methods, water-based methods, or both. We believe this change is necessary to advance the use of water-based cleaning methods."[63] The comment continues, "Additionally, we must emphasize that unless the Care Label Rule is more strictly enforced any change to the rules is of little value. Therefore, we support strengthening enforcement of the rule, including tightening the 'reasonable basis' requirements."[64] There has been no action on the Care Label Rule since the public comment period ended in the Fall of 1994.

Final Remarks

Perc is a highly regulated chemical, requiring dry cleaners to be informed of the regulations and committed to implementing workplace practices and emission control technology in order to comply with the law. The fact that regulations weigh heavily on the minds of dry cleaners is apparent from the advertisements in an industry trade magazine. Slogans such as "We guarantee our equipment will meet any and all state and federal environmental standards "[65] and "our customers, whether in NY or CA or any other state do not have to worry about compliance since Omega has designed machines to comply with present and future regulations" demonstrate this major concern. While the technology exists to reduce perc emissions, the machines currently in use at many dry cleaners (such as transfer and vented machines), are designed to last a long time. Transfer and vented machines are predicted to operate 15 to 20 years. However, theoretically, some transfer machines could last forever just by replacing parts. Interestingly, some of them were built by a companythat also built tanks.[66] This means that dry cleaners, who are mostly small businesses with little available capital, will most likely invest in new equipment only when the old equipment fails or when regulations require it. Therefore, regulations have been needed to keep pushing the industry toward updating equipment and working towards reducd emissions. Without regulations, small businesses will not need to update equipment until it is beyond repair despite the fact the emission reducing technology is available. Without regulations, the gains the dry cleaning industry has made in emissions reduction and perc usage can be expected to slow down.

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CONCLUSION

Our analysis shows that there are pros and cons to both perc dry cleaning and wet cleaning processes. In order to help policy makers, dry cleaners, and customers decide which method is preferable, we have summarized some of the advantages and disadvantages of both methods. Table 19 at the end of this section itemizes the following findings.

I. PERC DRY CLEANING PROS AND CONS

Perc is the primary solvent used by dry cleaners today. It enables them to clean clothes to standards that are satisfactory to their customers. Perc is easy to use, and most cleaners have made substantial investments in their equipment. In addition to these positive attributes, perc has several drawbacks. Among them are potential health problems for workers; environmental damage caused by the production, transportation, use and disposal of this toxic chemical; costs associated with disposing of perc; strict and retroactive liability for groundwater and soil contamination due to disposal of wastewater, and a complex regulatory atmosphere governing the use of perc. Recent regulations, new technology, and a commitment from dry cleaning associations to assist members in reducing emissions have all helped reduce the amount of perc used by 40 percent in the last five years[1], but there are still reasons for concern regarding perc use. The best available technology can only reduce perc emissions with proper maintenance and handling, but the fragmented nature of the industry makes it difficult to enforce new regulations and to ensure that dry cleaners are properly trained in good housekeeping practices. The pros and cons for perc are summarized below.

Health

It is commonly accepted that exposure to high levels of perc poses a serious threat to human health and can even result in death. However, the effects at long-term, low-level exposure, such as dry cleaners experience, have been harder to definitively identify. In the past two years, two key studies have found significant excesses of esophageal cancer[2] and elevated relative risk of leukemia[3] in populations exposed to perc. The results of these two studies are especially significant because previous studies, which only dealt with populations exposed to a variety of solvents used in the dry cleaning industry, were been unable to isolate the health effects of human exposure to perc.

Other studies of populations employed in the dry cleaning industry have suggested that perc may also cause additional negative health impacts such as reproductive and neurobehavioral problems. Many persistent toxins are shown to have a range of health effects beyond cancer, and we need to develop rigorous studies to determine the level of risk associated with perc exposure.[4]

There is already some evidence to suggest that workers and the general public are exposed to perc at levels which may negatively affect their health. For example, efforts to enforce more protective standards than currently exist have encountered barriers. A 1989 decision by OSHA to lower the exposure level from 100 ppm to 25 ppm was overturned on procedural grounds. Although states can impose stricter levels, the current carcinogen classifications are difficult to understand and are often incorrectly interpreted as risk assessments, which are used to determine exposure levels.

For example, even though the State of California has designated perc as a human carcinogen, and the International Agency for Research on Cancer (IARC) is proposing to upgrade its classification from a possible to a probable carcinogen, the U.S. EPA Science Advisory Board (SAB), during its 1991 review, felt existing scientific evidence was only sufficient to place perc on a continuum between a possible and probable human carcinogen. However, the SAB recognizes that many groups look to its standards to develop risk assessments. Therefore, it has cautioned that since there is widespread human exposure to perc, it would be wise to reduce worker exposure.

Environment

Perc is a volatile chemical, and as such has many negative environmental impacts. There are no known natural sources of perc. The 122,700 metric tons of fresh perc that are consumed by the commercial dry cleaning industry each year in the U.S. (see "Inventory Analysis") eventually wind up in the environment. Approximately two-thirds of this amount is released to the air. Some of the breakdown components of perc in the atmosphere, such as vinyl chloride, are toxic to humans. Other by-products have been shown to cause damage to plants and forests. Perc is also identified as a common indoor air pollutant, primarily in buildings located near a dry cleaning facility or in residences where freshly dry-cleaned garments are kept. Most of the remaining one-third of the perc that is not released to the atmosphere is captured in a solid form. This waste is classified as hazardous and therefore is disposed of in a low-level hazardous waste facility, or in a hazardous waste incinerator after additional perc reclamation takes place.

A primary concern is the perc being discharged into sewer systems each year. Once in the sewer system, perc can seep through concrete pipes and escape through sewer systems designed to leak. Perc is fairly mobile in soil and, once it reaches groundwater, remains stable and poses a risk to drinking water supplies. Numerous instances of perc-contaminated drinking wells have been reported across the country. In addition, perc manufacturing produces toxic chemical by-products. These chemicals pose additional environmental and health risks and must be disposed as hazardous substances. Lastly, newer perc dry cleaning machines employ emission control technology that reduces the amount of perc that escapes to the atmosphere. However, this results in an increase in the amount captured as a solid waste, and the energy requirement of this technology equipment is very intensive.

Performance

Perc is an excellent cleaning solvent that can clean a wide variety of garments with relative ease. It effectively dissolves lipophilic stains such as waxes, fats, and oils. However, it is incapable of dissolving water-soluble stains such as blood and perspiration. Therefore, perc is used in combination with spotting agents. Because perc only minimally penetrates fiber pores for most textiles and evaporates quickly, drying times are short, reducing the potential for garment shrinkage. However, some drying practices may result in small amounts of perc remaining in the garment after cleaning. Perc is not suitable for all garments. For example, perc can dissolve or melt beads, leaving behind stains which often cannot be removed. A sample of customers surveyed were satisfied with the look, smell and stain-removal results of professional perc cleaning.

Cost

Dry cleaning is an established business with a high chance of economic success. Indeed, an owner who is willing to put in long hours and work hard can be relatively certain to earn a reasonable profit. The technology is well understood, and a structure of industry groups that provide outreach and support has existed for some time. The dry cleaning economic data we gathered is largely based upon EPA's study comparing the cost and performance of dry cleaning and multiprocess wet cleaning. Our findings show that the dry cleaning facility will earn a yearly profit of about $16,000 to $20,000, depending on the discount rate used. We also found that increasing hazardous waste disposal costs are a concern for dry cleaners, as are the compliance costs resulting from increased regulation of perc and dry cleaning machinery. These factors can decrease the profit margin of a dry cleaner.

Regulations

Our analysis shows that perc is highly regulated and that these regulations translate into increased costs and time-consuming management practices for small commercial dry cleaners. The Resource Conservation and Recovery Act governs the use and disposal of perc, adding cost and record-keeping to dry cleaners who handle this toxic substance deemed a hazardous waste. The 1991 National Emission Standards for Hazardous Air Pollutants (NESHAP) for dry cleaners regulate the type of machine and emission control technologies that are allowable under the Clean Air Act. While NESHAP was intended to require Maximum Achievable Control Technology, in fact it has allowed certain machines to remain in use, such as transfer machines. Also, it does not ban carbon adsorbers, which create three times more separator water than do refrigerator condensers. When this water is poured down the sewer it can cause groundwater and soil contamination. This in turn causes liability problems for the dry cleaners who are caught under CERCLA's retroactive and strict liability clauses. CERCLA liability is one of the biggest concerns of dry cleaners today because of the huge expenses related to cleaning up a contaminated site. This type of contamination renders property virtually un-sellable, negatively impacting dry cleaners' financial solvency. Some states, such as California and Florida, recognize the potential environmental problems associated with perc use and are passing laws and taxes, more stringent than current federal policies, to protect the public and dry cleaners from exposure and from liability.

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[1]Personal communication with William Seitz, Executive Director, Neighborhood Cleaners Association, January 3, 1995.
[2]Avima M. Ruder et al., "Cancer Mortality in Female and Male Dry-Cleaning Workers," *JOM* 36 (August 1994).
[3]Ann Aschengrau et al., "Cancer Risk and Tetrachloroethylene-contaminated Drinking Water in Massachusetts," *Archives of Environmental Health* 48 (September/October 1993).
[4] Rebecca Head, "Health-Based Standards: What Role in Environmental Justice?" in B. Bryant (Ed.) *Issues, Policies, and Solutions for Environmental Justice*, (Ann Arbor, MI: University of Michigan, School of Natural Resources and Environment, 1994):51.

II. WET CLEANING PROS AND CONS

Because of some of these problems with perc, cleaners, environmental groups, and government agencies working on pollution prevention have begun looking for alternatives. The wet cleaning technique presented in our analysis uses primarily one wet cleaning machine to clean most of the garment stream and some multiprocess techniques to handle the remainder. Wet cleaning with machines is being tested in several areas in North America and Europe by professional cleaners and government-funded demonstration projects. There is currently a lack of comprehensive economic and performance data on the feasibility of cleaning all fine washables with the wet cleaning method described in this study. This is creating an atmosphere of skepticism and confusion among many dry cleaners around the country. Dry cleaners are concerned that wet cleaning will ruin garments and thus jeopardize business. Based on the five criteria of performance, environmental impacts, human health effects, cost, and regulations, wet cleaning appears to be less of a burden on the environment, and pose a lower risk to human health.

Health

Wet cleaning, as defined in this report, has been in operation for a relatively short period of time, no studies have evaluated the health impacts of the process. However, the adverse health impacts associated with conventional dry cleaning result primarily from exposure to toxic solvents, perc and the spotting agents. Since the primary difference between the two processes is that wet cleaning uses nontoxic soap and water, there will be significantly fewer health impacts with wet cleaning.

Environment

The alternative wet cleaning system we analyzed poses none of the environmental problems associated with perc use. No hazardous wastes or regulated air emissions are produced. Moreover, the electricity requirements of the wet cleaning system are less than that of the dry cleaning system, because energy intensive emission control technology is not needed. The most significant environmental impact associated with wet cleaning is the significantly higher amount of water required to wet clean clothes. This is especially a concern in areas of the country where water resources are limited. Further developments in water recycling, reuse, and on-site treatment can substantially reduce the amount of water required.

In regions where water is in abundant supply, the wet cleaning process clearly poses the lowest environmental burden. In areas where water is limited, a determination of the environmental advantages of wet cleaning is less clear. Water used would be weighed more heavily and specific impacts of increased water consumption would need to be quantified.

Performance

For the majority of fabrics, water does not dissolve or weaken fibers or cause bleeding of dyes, and water is compatible with readily available detergents. Wet practitioners supplement water cleaning with nonhalogenated solvents to remove lipophilic stains. The main concern with wet cleaning is water's thorough penetration into the fiber pores of many textiles. Excess water can result in misshapen garments or longer drying times, which potentially cause garment shrinkage. However, sophisticated machine technology and careful sorting enables wet cleaners to precisely control drying times, residual water contents, and mechanical action to avoid garment shrinkage. During its "Green Clean" demonstration project, Environment Canada had only one claim for garment shrinkage problems out of the 1,460 garments cleaned. Although debate exists over how to test for the cleanliness of wet-cleaned clothes, initial demonstration results of wet cleaning are extremely positive. Green Clean has received a 97 percent favorable response from customers, and European wet cleaner Elisabeth Winter reports fewer problems with cleaning garments with trims and accessories.

Cost

Wet cleaning, contrary to dry cleaning, is a new and unfamiliar business. This study analyzed a wet cleaning operation that uses a combination of wet machine technology and multiprocess wet cleaning. The economic analysis of wet cleaning was based on data from Aqua Clean System manufacturers, Environment Canada, and Ecomat. Our analysis found that a wet cleaning facility could earn a yearly profit of $17,000 – $20,500, similar to the profits earned by a dry cleaner.

Wet cleaning may become increasingly attractive to professional cleaners because the detergents used in wet machines are not regulated. Consequently, hazardous waste disposal costs are avoided and liability is greatly reduced. In comparison with dry cleaning, wet cleaning also involves a smaller up-front capital investment. Additionally, electricity usage is significantly less, in part because pollution control equipment is not required. However, wet machines require large amounts of water, which drive up operating costs. The largest economic uncertainty surrounding wet cleaning is the amount of labor required to press wet-cleaned clothes. Estimates of the labor needed for spotting and pressing in a wet cleaning facility vary considerably. In fact, the question of whether or not wet cleaning can clean a given quantity of clothes at a lower cost than dry cleaning hinges upon assumptions about labor rates. However, existing wet cleaners have used two important measures to keep down pressing rates and remain competitive in the clothes cleaning business. First, existing wet cleaners are careful not to over-dry garments, which creates excessive wrinkling and pressing requirements. Second, some wet cleaners have invested in worker training to further reduce differences in labor rates.

Regulations

Wet cleaners do not have to comply with the myriad of federal and state environmental regulations that perc dry cleaners must comply with because wet cleaners do not use toxic chemicals. Wet cleaners should contact their local Publicly Owned Treatment Works (POTWs) and report the type and volume of wastewater they produce, as well as any concentrations of organic and inorganic chemicals in the wastewater. Reporting varies among POTWs and, because there are only a few wet cleaners operating in the United States, it is unclear what type of future regulations there may be governing wastewater to sewers. Presently, POTWs are not concerned with the quality of wastewater from wet cleaners because they are using phosphate-free detergents which biodegrade at their treatment facilities. However, the volume of water could be an issue for POTWs in the future if the entire garment care industry switched to wet cleaning.

TABLE 19 - SUMMARY OF FINDINGS OF A MULTICRITERIA COMPARISON OF PERC DRY CLEANING AND A WET CLEANING SYSTEM

<table>
<tr><th>Criteria</th><th>Perc Dry Cleaning</th><th>Wet Cleaning</th></tr>
<tr><td>Human Health</td><td>• Strong evidence suggests the human carcinogenicity and neurotoxicity of perc.</td><td>• Little or no toxicity is associated with inputs to the cleaning process.</td></tr>
<tr><td>Environmental</td><td>• Perc is a chlorinated compound. Over 269 million pounds of perc were used by commercial U.S. dry cleaners in 1991.
• Numerous problems are documented on perc releases into air, land, and water.
• Emission-control technology is energy-intensive.</td><td>• Principal inputs are water and nontoxic cleaning agents, so there are minimal adverse impacts.
• The process uses significantly more water. This could be partially mitigated by recycling the water.
• Machines operate on less energy.</td></tr>
<tr><td>Performance (i.e., cleanliness and appearance of garments)</td><td colspan="2">• Based on the limited testing of wet cleaning, both systems show advantages and disadvantages. Specific performance results are dependent upon fiber type, garment construction, machine technology, and process.
• Both cleaning systems produce results which appear satisfactory to customers.</td></tr>
<tr><td>Economic</td><td colspan="2">• Additional wet cleaning cost data is needed.
• Preliminary analysis indicates that the two methods have roughly comparable costs and profits.
• Estimates of the profitability of wet cleaning hinge on assumptions regarding wet cleaning's labor requirements.</td></tr>
<tr><td>Regulatory</td><td>• Many federal, state, and local regulations govern perc use and releases to air, land, and water.</td><td>• Minimal regulatory burdens on professional cleaners exist.</td></tr>
</table>

III. NEXT STEPS

Given the diversity of garments being worn today and the trend in fashion toward more casual wear, wet cleaning certainly has a future in the professional cleaning industry. Initial results from demonstration projects are showing wet cleaning (using new machines and some multiprocess techniques) to be a viable cleaning alternative, with fewer negative impacts on the environment, human health, and professional cleaners' profits. The critical question is whether wet cleaning can replace perc dry cleaning or should just be used to supplement it, cleaning only a portion of the clothing stream.

While our study emphasized the importance of five criteria (environment, human health, economics, performance, and regulations), the dry cleaning industry has expressed concern about the performance and economic criteria: if wet cleaning cannot meet the base level of performance established by dry cleaning, it will not be acceptable to customers; if it is not economical for small commercial dry cleaners, it will not be adopted voluntarily. These comparisons are difficult to conduct at this point, since wet cleaning technology and practices are still evolving. Most wet cleaners have been operating for less than one year and their business is being compared to an industry with over 40 years of experience. Until wet cleaners have been operating long enough to collect empirical data on both cost and performance, dry cleaners will continue to maintain a level of skepticism about the practicality of wet cleaning. The recommendations in the next section address these concerns.

RECOMMENDATIONS

Growing evidence suggests that wet cleaning may be a viable alternative to dry cleaning, but existing data are limited and further information is needed before a significant number of independent cleaners are likely to invest in wet cleaning technologies. Given existing uncertainties, wet cleaning is likely to be viewed by most cleaners as too risky an investment in terms of the operating costs and performance. The following recommendations offer a conservative approach to moving ahead with wet cleaning given that existing gaps in data prevent a more comprehensive comparison of wet and dry cleaning. We identified four general categories of recommendations. Each category is briefly described below. More specific recommendations under these headings are then provided in the remainder of the section.

- **Data Collection** - Additional studies are needed to clarify and quantify existing uncertainties. Studies should be structured with input from all involved stakeholders to ensure that data collected are both accurate and well accepted.

- **Incentives** - The government can play a key role in supporting experimentation with alternative cleaning technologies. A variety of economic incentives could encourage cleaners to set up alternative cleaning systems. The government could also use these shops to collect data for further evaluation of alternative cleaning technologies.

- **Information Dissemination** - Once data are available, the government could act as an information clearinghouse, providing information pertaining to demonstration project data, regulatory changes, concerns of stakeholders, etc. It is important to recognize that consumers are an important stakeholder in this process, one that should participate in the information exchange.

- **Implementation** - Shop owners who are thinking about expanding capacity should consider purchasing a wet cleaning machine. This will provide both the cleaners and their customers with additional cleaning options. Additionally, it may allow the owner to clean certain garments, such as those made of suede and leather, which most dry cleaners have not previously been able to clean on-site.

I. DATA COLLECTION

In conducting this analysis, a number of areas were identified where comprehensive data are lacking. Based on our comparative analysis of wet and dry cleaning, we recommend studying the following issues:

- Concern exists that wet cleaning may damage clothing after many washings. Consequently, a study should be conducted to examine the long-term impacts of repeatedly wet cleaning a garment over its useful life. Results should be compared to the repeated dry cleaning of similar garments, to determine if either process impacts the useful life of a garment.

- A study better quantifying the labor requirements of wet cleaning compared with dry cleaning should be conducted. This is especially important in light of the fact that labor costs constitute roughly 40 percent of an average dry cleaner's costs.

- There is concern that spotting chemicals, needed to remove grease-based stains, may be rinsed out and captured in wash water during the cleaning cycle. This wash water is ultimately discharged into the sewer system, posing potential water quality problems. We need to better understand the toxicity and risks associated with spotting chemicals being discharged with a wet cleaner's wastewater.

- We cannot be sure that a given level of regulation is either effective or appropriate without a better understanding of health risks related to perc. A more accurate dose-response model must be developed to better predict the effects of various levels of perc exposure. Based on these findings, and data concerning human exposure, the carcinogenicity classification for the chemical should be appropriately modified. Such a reclassification should lead to protective measures for populations exposed to high levels of perc.

- Concern exists that wet machine technologies may not be viable for low-volume cleaners. Wet machine technologies require a significant amount of sorting to assure that loads put into a wet machine are of similar fabric-type and color. Demonstration projects should analyze how profitable wet cleaning is under a range of variables such as the volume and mix of garments and fabric types received by the cleaner.

- Concerns exist about the large amount of water needed to operate a wet cleaning facility. However, certain wet cleaning machines such as the Aqua Clean machine can be adjusted to recycle water used in the last rinse cycle for use in the original soaking of the subsequent load. In this manner, wet cleaning technology can be made more water efficient. Further study should examine other ways to make water use in wet cleaning more efficient. This is especially important for wet cleaning if it is to be established in water-scarce regions in the country.

- It remains unclear exactly what customers want from professional cleaning. Data need to be collected on customer expectations of performance and service time as well as studying customer attitudes toward alternative cleaning technologies.

- To improve both testing procedures and the acceptance of their results, professional cleaners should be more involved in designing, monitoring, and evaluating future studies of wet cleaning. To achieve this, future studies should be conducted at an independent lab, with testing performed by a party acceptable to both dry cleaners and alternative advocates. Additionally, testing at actual cleaning shops would provide a more realistic environment for evaluating technologies. Hopefully, by working together to solve uncertainties, a better working relationship can be developed by the various parties involved in this issue.

II. INCENTIVES

There is some concern about the data collection from current demonstration projects since they are not run by actual cleaners but by the government. For example, it is difficult to draw conclusions about the profitability of wet cleaning from the Environment Canada project because prices were intentionally set above the market rate so that the agency would avoid negatively impacting competing dry cleaners. Future efforts should focus on encouraging existing dry cleaners to expand their use of alternative technologies. Such encouragement could be achieved in a number of ways.

- Either EPA or the Small Business Administration could offer loan guarantees, low-interest loans, or other subsidies to cleaners willing to experiment with alternative cleaning technologies.

- State, and local governments could also encourage the establishment of private demonstration projects by existing cleaners. This could be achieved by government agencies leasing alternative technology equipment to cleaners for a reasonable rate, allowing the lease to be canceled at any time. Or government could provide some amount of financial insurance to assure a cleaner that they would not go out of business by converting to wet technologies. Again, the idea would be to encourage cleaners to experiment with alternatives by reducing the financial risk involved in such a conversion. In return, there would be a larger set of cleaners from which to gather information useful in further evaluating alternative cleaning systems.

- The government should offer tax breaks to cleaners who purchase wet cleaning equipment and/or retire older dry cleaning equipment.

- The government could subsidize training programs for wet technologies. The availability of training and trained workers would encourage expansion by dry cleaners interested in wet cleaning but concerned that they do not have the skilled labor necessary to adopt wet technologies.

- The federal government should change garment labeling regulations. Care labels which currently read "dry cleaning only" should be changed to "professionally clean." This will allow cleaners more flexibility in deciding how to clean individual garments, based on their fabric type and cleaning needs.

III. INFORMATION DISSEMINATION

For dry cleaners to adopt wet cleaning, buth they and their customers need more information. As part of this strategy, the government should act as an information clearinghouse. It could provide cleaners with practical information regarding converting to an alternative technology, as well as providing the public with information regarding the pros and cons of wet cleaning.

- The government should publish a guidebook providing cleaners with practical information about which technologies and equipment are appropriate for specific circumstances. Information about existing wet clean machines is limited by the fact that they have not been on the market for very long, so it is difficult for cleaners to know which machine would be most appropriate for them; the guidebook could describe the strengths and weaknesses of each machine. Descriptions of existing shops could be used as models of how wet cleaners are able to remain competitive. This could discuss how to increase revenue through diversifed operations (e.g., owning a coin-operated laundromat, processing industrial garments; and/or operating several drop-off sites while actually processing all garments at a central facility.) The guidebook could be jointly developed by the EPA, environmental groups, and dry cleaning trade associations.

- In conjunction with the guidebook, a training program could be developed to provide cleaners with the practical information required to own and operate alternative wet cleaning technologies. Additionally, running the training program at successful wet cleaning shops could provide owners with a chance to see firsthand that wet cleaning can be successfully and profitably implemented. The Neighborhood Cleaners Association has already started to provide training in operating wet clean technologies, and other professional cleaning associations should be encouraged to do the same.

- An important aspect of information dissemination will be to provide customers of professional cleaners with information about cleaning services. At least in the short run, consumers will determine whether or not a wet cleaning facility will be viable. Thus, wet cleaners and proponents of wet cleaning need to better market the technology. In order for consumers to make an educated choice, efforts need to be made to provide consumers with information about the cost, performance, health, and environmental impacts of each technology. For example, environmental groups and/or EPA might fund the creation of a brochure outlining the pros and cons of various professional clothes cleaning options. The brochure would be especially important in overcoming informational barriers that may exist.

IV. IMPLEMENTATION

Dry cleaners who are considering the purchase of an additional machine to expand the volume of clothes they can clean, or large dry cleaners that are thinking about replacing one of their existing machines, should consider buying a wet clean machine. This would provide both cleaners and their customers with greater flexibility in choosing how to clean garments.

- Owning both wet and dry cleaning equipment would allow professional cleaners to experiment and compare the technologies. Having both technologies would allow the operators to choose the methods they find to perform best, based on the fabric type and cleaning needs of the individual garments.

- Purchasing a wet machine would expand the types of garments that the cleaner can actually process. For example, dry cleaners typically ship leather and suede garments off-site for special cleaning since perc cleaning stiffens these fabrics and can cause their colors to fade. However, with the use of specially designed finishing agents, leather and suede can be cleaned in wet machines. In this manner, owners of wet machines may be able to increase profit by being able to process a larger percentage of garments on-site.

For additional information on wet cleaning machines that are on the market today, we would encourage readers to refer to Appendix H, which reproduces a document issued by the Center for Neighborhood Technology called "Wet Clean Machines." The document includes names and phone numbers of wet cleaning machine manufacturers, equipment costs, and detailed descriptions of machine features.

EPILOGUE

The political climate of the country has changed dramatically since we began our research on this issue. In April 1994, the majority party in the U.S. Senate and the House of Representatives was the Democrats, whose platform generally supported environmental regulations. In November 1994, the election brought in a wave of anti-regulatory, "cut government spending" legislators. The Contract With America, spearheaded by House Speaker Newt Gingrich, set the tone for an attack on unfunded mandates such as environmental, worker health, and safety regulations. Although there is a great deal of uncertainty about how far this movement will go, it is important to note that many of the regulations currently governing the dry cleaning industry could be changed by Congress within the next few years. In our opinion, if these legislators want to roll back regulations without sacrificing health, safety, and the environment, they should be promoting pollution prevention strategies. Emission control laws would not be needed if the pollution was not generated in the first place.

One law in particular illustrates this point. Superfund is due for reauthorization in the 104th Congress, and there is currently a movement to cut the retroactive liability clause. However, no alternative funding source has been suggested. Though the clause is less than perfect, it still provides a mechanism for assigning responsibility for the cleanup of contaminated sites. If polluters who caused the pollution several years ago, albeit unknowingly, are no longer required to pay for the cleanup, and the Congress is simultaneously cutting government spending, who will pay? Will we live with the pollution or will local citizens or individual state or local governments have to pay for the cleanup?

The most logical way to avoid this dilemma is to decrease the use of toxic chemicals today, regardless of what the liability laws may look like in the future. While regulations make it more expensive to run a small business, they are designed to reduce the public's exposure to pollution. They are a mechanism for ensuring that all people have a clean and healthy environment to live and work in without having to bear the burden of other people's pollution. If small businesses are to avoid the expense of complying with regulations, they should reduce their use of hazardous chemicals.

Pollution prevention through source reduction, such as reductions in perc use, translates into savings for cleaners in the short-term and the long run. Industry associations assert that cleaners can realize a substantial savings by installing improved emission control technologies that use perc more efficiently. By reducing the amount of perc used and disposed of, these new technologies will pay for themselves in a short time period. Regardless of whether the reductions in perc use are mandated by law or are initiated voluntarily by a responsible industry, they will save money for both the cleaners and the public in the long run.

Private wet cleaners, just like private dry cleaners, are in business to make a profit, not to save the environment. This report outlined a host of regulatory requirements all stemming from the hazardous nature of perc. One way to cut back on the extent and cost of regulation for businesses and taxpayers is to eliminate the use of perc and other chemicals that have an inherently high "demand" for regulation. The contrast between perc dry cleaning and wet cleaning illustrates the enormous benefit of eliminating toxic substance use entirely. By eliminating the need to use a highly regulated chemical such as perc, one wet cleaner in New York City is finding that wet cleaning passes a benefit-cost test. In summary, wet cleaning seems to make good sense even if today's regulatory hammers are gone tomorrow.

APPENDICES

APPENDIX A - CALCULATIONS OF INVENTORY ANALYSIS DATA

To eliminate redundancy, some of the calculations for the inventory section appear in other appendices, as noted below.

Dry Cleaning Process:

1. Perc Requirements (Perc mileage):

Low Range: (79,958.2 lbs. clothes/year) / (1,800 lbs. clothes per gal. perc) = 44.42 gal. perc/year

Middle Range: (79,958.2 lbs. clothes/year) / (545.45 lbs. clothes per gal. perc) = 146.59 gal. perc/year

High Range: (79,958.2 lbs. clothes/year) / (333 lbs. clothes per gal. perc) = 240.11 gal. perc/year

2. Energy Requirements:

Dry Cleaning Machine: See Appendix C, # 2.

Emission Control Equipment: See Appendix C, # 4 and #6.

Total: The total energy requirements for the dry cleaning system is the sum of requirements for the machine and emission control units. These total 14,136.46 kWh of electricity required per year to operate the dry cleaning machine.

3. Air Emissions:

At the low end of this range of emission factors, 2,270.81 pounds of perc per year are emitted to the atmosphere:

Process emissions:

(0.44 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 351.82 lbs. perc/year

Fugitive emissions:

(2.40 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 1,918.99 lbs. perc/year

Total air emissions:

(351.82 lbs. perc/year) + (1,918.99 lbs. perc/year) = 2,270.81 lbs. perc/year

At the high end of the range of emission factors, 2,958.45 pounds of perc per year are emitted:

Process emissions:

(1.6 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 1,279.33 lbs. perc/year

Fugitive emissions:

(2.1 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 1,679.12 lbs. perc/year

Total air emissions:

(1,279.33 lbs. perc/year) + (1,679.12 lbs. perc/year) = 2,958.45 lbs. perc/year

4. Solid Waste Outputs:

Solid Waste Generation Factors: At the low end of the range of solid waste generation factors, 479.75 pounds of solid waste would be produced each year:

(0.6 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 479.75 lbs. solid waste per year

At the high end of the range of solid waste generation factors, 1919 pounds of solid waste would be produced each year:

(2.4 lbs. of perc) / (100 lbs. of clothes) x (79,958.2 lbs. of clothes/year)
= 1919 lbs. solid waste per year

Filters: After 7,800 pounds of clothes have been cleaned, a total of eight filters will require disposal. At the activity level we have assumed, 10.25 replacements are required per year:

(79,958.2 lbs. of clothes) / (7,800 lbs. clothes per filter) = 10.25 filter replacements.

Each of the 10.25 replacements consists of eight filters: the six carbon core filters in the two cartridges, and two double all carbon filters. Thus, a total of 82 filters are required throughout the year:

(10.25 replacements) x (8 filters per replacement) = 82 filters

Still Bottoms: The range of estimates of still bottom generation is from 0.5 gallons per 1,000 pounds of clothes cleaned to 3.0 gallons per 1,000 pounds of clothes cleaned. At the low end of the range, the dry cleaning machine would produce 39.98 gallons of still bottom waste per year:

(79,958.2 lbs. of clothes/year) x (0.5 gallons/1,000 lbs. clothes) = 39.98 gallons/year

At the other end of the range, 239.87 gallons of still bottoms would be produced:

(79,958.2 lbs. of clothes/year) x (3.0 gallons/1,000 lbs. clothes) = 239.87 gallons/year

Wet Cleaning Process:

1. Detergent Requirements:

To determine the amount of detergent used by Ecomat, the following calculations are performed. At 56 loads per week and 1/4 cup of detergent per load, the yearly detergent use would be 45.5 gallons:

(.25 cups per load) x (56 loads/wk) x (52 weeks/year) = 728 cups/yr.
(728 cups/yr.) x (8 ounces/cup) x (1 gallon/128 ounces) = 45.5 gallons/yr.

To determine the amount of detergent used by Aqua Clean, see Appendix D, # 13.

2. Electricity Requirements:

To see the calculations for electricity requirements of the wet cleaning machine, see Appendix D, # 3.
To see the calculations for electricity requirements of the dryer, see Appendix D, # 4.
The total electricity use for both machines is 6,338 kWh/yr.

3. Water Requirements:

See Appendix D, #18.

APPENDIX B - HEALTH RELATED INFORMATION

The following appendix contains:

1. *Rachel's Environment & Health Weekly #416*, "The Scientific Basis of Chemical Safety--Part 2, Standards that Kill."

2. Excerpts from OSHA Regulations on Air Contaminants, "Health Effects Discussion and Determination of Final PEL," *Federal Register* v.54, p. 2670, January 19, 1989.

Rachel's **Environment & Health Weekly #416**

Providing news and resources for environmental justice -- November 17, 1994

The Scientific Basis of Chemical Safety--Part 2
STANDARDS THAT KILL

As we saw last week, Threshold Limit Values (TLVs) are air pollution limits for the workplace. Since 1946, TLVs have been devised and published by a private organization called the American Conference of Governmental Industrial Hygienists (ACGIH), a private group composed of industrial hygienists from state and local governments, plus academics and industry consultants. ACGIH clearly wants its audience to believe that TLVs are health-based standards; the preface to ACGIH's annual TLV list says TLVs "are health-based recommendations derived from assessment of the available published scientific information from studies in exposed humans and from studies in experimental animals." Furthermore the preface to the annual TLV list says TLVs are airborne concentrations "to which nearly all workers may be exposed for 8 hours per day, 40 hours per week for a working lifetime without adverse effect."[1]

In 1970 Congress created the Occupational Safety and Health Administration (OSHA) to protect workers from injury and from toxic chemicals. In 1971, OSHA adopted the ACGIH's 1968 TLVs as official workplace standards called PELs (permissible exposure limits). The rationale at the time was that the Occupational Safety and Health Act (OSH Act) required OSHA to adopt standards quickly and there was no time to develop independent standards. However, the OSH Act created a new process for OSHA to follow in establishing future PELs, and it created a National Institute for Occupational Safety and Health (NIOSH) with official responsibility for providing scientific advice to OSHA. During the next 20 years, NIOSH developed and published Recommended Exposure Limits, or RELs, for 160 chemicals. However, OSHA ignored the bulk of NIOSH's recommendations and adopted only 12 new PELs during the 20-year period.

During the 20 years that OSHA spent setting 12 new PELs, the ACGIH TLV Committee revised 234 TLVs downward, making them more protective (and stricter than the corresponding PELs which had been adopted in 1970 but never revised), and adopted 168 new TLVs for which there were no PELs. By 1987, official PELs were lagging badly behind the development in TLVs, and this was a source of embarrassment to OSHA. In the spring of 1987 OSHA began a formal procedure to adopt a new Air Contaminants Standard. OSHA proposed to adopt, once again, all of the ACGIH's TLVs (in their 1987 revision).[2]

During the next 2 years, TLVs came under close scrutiny. In 1988, two occupational hygienists, Barry Castleman and Grace Ziem, examined the official documentation that ACGIH said it had relied upon in setting TLVs. (See *REHW #128*.) Castleman and Ziem reported that at least 104 of the TLVs were based on nothing more than unpublished allegations, often made to the TLV committee by industry scientists whose employers had a direct financial interest in the particular substance being considered.[3]

Despite this information, OSHA continued proposing to adopt all TLVs as official PELs.

During public hearings on the proposed Air Contaminants Standard in 1988, NIOSH placed 4000 pages of testimony in the record. They offered evidence that at least 98 of the 400 proposed PELS would not protect the health of workers. For 50 of the 98 substances, NIOSH had already published Recommended Exposure Limits (RELs). NIOSH's average (mean) REL was 71 times lower (more protective) than the corresponding TLV.

During the public hearings, the New Jersey State Department of Health (NJSDOH) placed in the record a study that it had conducted of existing and proposed PELs, using EPA's [U.S. Environmental Protection Agency's] Integrated Risk Information System (IRIS) database.[4]

The IRIS database was created by EPA to collect and systematically review human and animal toxicity data on particular chemicals. The IRIS database in 1990 contained reviews of 370 chemicals. The purpose of the IRIS system is to support EPA and other governmental regulators in their efforts to protect public health.

NJSDOH researchers randomly selected 43 existing and proposed PELs. Using widely-accepted risk assessment methods to extrapolate from reference doses and unit risks in the IRIS database, the NJSDOH researchers calculated health-based occupational guidelines. For the 43 chemicals, the average (mean) existing PEL was 9.5 mg/m^3; the average (mean) proposed PEL was 7.5 mg/m^3; and the average (mean) health-based guideline calculated by NJSDOH was 0.004 mg/m^3. Thus average existing PELs exceeded NJSDOH's health-based guidelines by a factor of 2375 and proposed PELs exceeded NJSDOH's health-based guidelines by a factor of 1875, on average. The New Jersey State Department of Health concluded that OSHA's proposed PELs were based on outdated information and weak methodology and would not protect worker health.

Despite these compelling criticisms, OSHA formally adopted all of ACGIH's TLVs as enforceable PELs in January 1989. As a practical matter, this astonishing decision had the effect of making ACGIH's TLV Committee the de facto workplace-standards-setting body in the U.S. Since the TLV Committee operates behind closed doors without peer review of its methods or conclusions, this transfer of authority from OSHA to ACGIH effectively gutted the OSH Act, which had established a public process for setting occupational standards. (In July 1992, a court declared the new PELs illegal, thus re-establishing the 1971 PELs, based on the 1968 TLVs, as official U.S. standards; the Clinton administration did not appeal that court ruling.[5])

Now, as we saw last week, the TLVs themselves have been subjected to withering criticism. Although they are called *threshold* limit values, implying that they are set at a level that would *prevent* disease, in many cases they have been set at or above levels at which disease is known to occur in humans.

For example, 7 of 14 workers exposed to chlorodiphenyl at 10% of the TLV suffered chloracne; 10 out of 10 volunteers exposed to ethyl ether suffered upper respiratory tract irritation at 75% of the TLV; and 5 out of 5 volunteers exposed to 2-nitropropane suffered central nervous system effects such as headaches, nausea, and vomiting at 80% to 180% of the TLV. In the Air Contaminants Standard, OSHA set the PEL for these three substances at the same level as the TLV.[6]

Today the ACGIH and its TLVs are being subjected to a continuous stream of criticism from knowledgeable authorities. For example, a well-known industrial hygienist in New Jersey recently said, "The reality is that for the vast majority of chemicals, we have little or no chronic toxicity data. Even when we do, we usually don't know the chemical's effects on lung function, nervous system function, immune or endocrine system function, reproductive function, or other vital bodily functions. Without such data, claims that we know what exposures are permissible and will not harm workers are false.

"They [ACGIH] still have not acted rigorously to avoid conflicts of interest among members, however. Instead of requiring disclosure of corporate consulting relationships, they are using an honor system where members merely state upon appointment that they have no conflicts of interest. While some positive changes have been made, they do nothing to undo the damage already done by the present TLVs which were set under the old, dysfunctional system, and the changes do not go far enough to ensure that past mistakes will not be repeated.

"Exposure limits are theoretically helpful to workers. However, if we don't get the numbers right, and it looks like ACGIH and OSHA usually have not, then they are harmful."[4]

In 1993, a researcher recalled a 1956 criticism of TLVs: "In the introduction to its 1956 list... the Committee on Threshold Limits says, 'Values are given... for the maximum average atmospheric concentrations of contaminants to which workers may be exposed... without injury to health.' Careful study of the data which support the currently accepted values suggests that no such description can be truthfully attached to most of them."[7] [The ... appear in the 1993 original.]

A July 1994 analysis of TLVs finds that 229 of the approximately 600 current TLVs have been criticized, in one technical forum or another, as inadequate to protect workers' health.[8]

What then is the purpose of TLVs, if not to protect the health of workers?

In 1935, a group of industrialists met to devise a comprehensive response to the "industrial dust problem." At that time, lawsuits were pending, demanding hundreds of millions of dollars in damages for occupational lung disease. This meeting led to the formation of the Air Hygiene Foundation in 1936, with 200 corporations and trade associations as members. One goal of the Foundation was to set up "authoritative and approved standards for the control of industrial dusts which, if complied with by industries, or by industrial companies, will act as a defense against personal injury suits."[8]

Though TLVs often may not protect the health of workers, they do provide what is now commonly known as the "TLV defense" when a company is sued for harming workers by exposing them to toxic chemicals. The typical TLV defense quotes the ACGIH saying TLVs are "thought to be safe for workers -- based on the best available information." The winners in this sad affair are the business interests and lawyers who use the TLV defense as a shield from liability in personal injury lawsuits. The losers are the 50,000 to 70,000 workers who die each year from diseases they developed after exposure on the job, and the estimated 350,000 workers who develop new cases of occupational disease each year from toxic exposures.

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[1] TLV documents quoted in Ernest Mastromatteo, "TLVs: Changes in Philosophy," *Applied Industrial Hygiene* Vol. 3, No. 3 (March 1988), pgs. F12-F16. In 1988, Mastromatteo was head of ACGIH's TLV Committee.

[2] James C. Robinson and others, "Implications of OSHA's Reliance on TLVs in Developing the Air Contaminants Standard," *American Journal of Industrial Medicine* Vol. 19, No. 1 (January 1991), pgs. 3-13.

[3] Barry I. Castleman and Grace E. Ziem, "Corporate Influence on Threshold Limit Values," *American Journal of Industrial Medicine* Vol. 13, No. 5 (1988), pgs. 531-559.

[4] Eileen Senn Tarlau, "Guest Editorial; Industrial Hygiene With No Limits," *American Industrial Hygiene Association Journal* Vol. 51, No. 1 (January 1990), pg. A9-A10.

[5] Frank Swoboda, "Some Toxic-Substance Rules Being Dropped; Administration Did Not Appeal Court Decision," *Washington Post* March 23, 1993, pg. D1.

[6] S.A. Roach and S.M. Rappaport, "But They Are Not Thresholds: A Critical Analysis of the Documentation of Threshold Limit Values," *American Journal of Industrial Medicine* Vol. 17, No. 6 (1990), pgs. 727-753.

[7] Henry Smyth Jr., 1956, quoted in S.M. Rappaport, "Threshold Limit Values, Permissible Exposure Limits, and Feasibility: The Bases for Exposure Limits in the United States," *American Journal of Industrial Medicine* Vol. 23, No. 5 (May 1993), pgs. 683-694.

[8] Barry I. Castleman and Grace E. Ziem, "American Conference of Governmental Industrial Hygienists: Low Threshold of Credibility," *American Journal of Industrial Medicine* Vol. 26, No. 1 (July 1994), pgs. 133-143.

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The following are sections from OSHA Regulations on Air Contaminants (1910.1000) can be found in the Federal Register v. 54, p. 2668, 2670, 2686-2689, Jan. 19, 1989.

VI. Health Effects Discussion and Determination of Final PEL
C. Description of the Substances For Which Limits are Being Revised or Established
15. Substances for Which Limits Are Based on Avoidance of Cancer

(Page 2868)
Introduction

This group comprises 16 substances for which the ACGIH or NIOSH has recommended new or revised limits based on evidence that occupational exposure may be associated with an increased cancer risk. Table C15-1 lists the former OSHA permissible exposure levels (PELs), the proposed PELs, the PELs established in the final rule, and the CAS and HS numbers for these substances. OSHA is proposing to revise existing TWA and/or STEL limits for six substances, retain a PEL for four substances currently listed on Table Z-2, and add limits for four substances not currently listed on OSHA's Z tables. For one previously unregulated substance, chromyl chloride, OSHA has concluded that a separate 6(b) rulemaking is appropriate. For one substance OSHA is not establishing an exposure limit at this time.

(Page 2670)
TABLE C15-1. Substances for Which Limits Are Based on Avoidance of Cancer

H.S. Number/ Chemical Name	CAS No.	Former PEL(1)
1308 Perchloroethylene	127-18-4	100 ppm TWA 200 ppm STEL (5 min/3 hr 300 ppm Ceiling

(Pages 2686-2689)
PERCHLOROETHYLENE (TETRACHLOROETHYLENE)
CAS: 127-18-4; Chemical Formula: CCl(2) = CCl(2)
H.S. No. 1308

OSHA's former permissible exposure limits for perchloroethylene (tetrachloroethylene) were 100 ppm as an 8-hour TWA, 200 ppm as a STEL not to be exceeded for more than five minutes in any three-hour period, and 300 ppm as a ceiling. On the basis of the chemical's narcotic effects in humans, the Agency proposed a revised PEL of 50 ppm TWA and a 15-minute STEL of 200 ppm for perchloroethylene; these are the limits recommended by the ACGIH (ACGIH 1986/Ex. 1-3, p. 464). NIOSH (Ex. 8-47, Table N6B) did not concur with the proposed limits and recommended that exposures be maintained at the lowest feasible limit and that this chemical be classified as a potential occupational carcinogen. OSHA has evaluated the health evidence for this substance and has determined that a further reduction in the PEL to 25 ppm as a TWA is warranted, and the Agency is establishing this limit in the final rule. Perchloroethylene is a clear, colorless, nonflammable liquid with an etheral odor.

Perchloroethylene is widely used as a solvent in the dry cleaning industry and in industrial degreasing operations. The narcotic effects associated with exposure to high levels of this chemical are well documented. A worker exposed to an estimated concentration of 1470 ppm perchloroethylene and Stoddard solvent for 3.5 hours lost consciousness (Stewart, Erley, Schaffer, and Gay 1961/Ex. 1-807). The most comprehensive studies of the effects of prolonged exposure to perchloroethylene vapors on human volunteers were conducted by Stewart and colleagues (Stewart, Hake, LeBrun et al. 1974/Ex. 1-970; Stewart, Hake, Wu, et al. 1977/Ex. 1-971); these investigators concluded that prolonged exposure to 200 ppm results in early signs of CNS depression, while no response was elicited in men or women exposed repeatedly to 100 ppm for seven hours/day, except that performance on the Flanagan coordination test was significantly decreased in some exposed subjects (Stewart, Hake, Wu et al. 1977/Ex. 1-971, p. 28).

Based on these findings, the Agency concluded that its former PEL permitted workers to be exposed to a significant risk of CNS effects. In addition to examining the evidence for the chemical's narcotic effects, OSHA has reviewed a number of studies on the carcinogenicity of perchloroethylene. These investigations are summarized below.

In a 1977 gavage bioassay for carcinogenicity, perchloro-ethylene proved to be a liver carcinogen in mice but not in rats (NCI 1977c, as cited in ACGIH 1986/Ex. 1-3, p. 464). In 1986, the NTP conducted an inhalation bioassay of perchloroethylene (NTP 1986b/Ex. 8-31, Appendix 4), in which groups of 50 male and 50 female F344/N rats and B6C3F1 mice were exposed to perchloroethylene for six hours/day, five days/week, for two years. The exposure concentrations were 0, 200, or 400 ppm for rats and 0, 100, or 200 ppm for mice. Male and female rats exposed to either 200 or 400 ppm developed statistically significant increases in mononuclear cell leukemias. According to the NTP report (NTP 1986b/Ex. 8-31, Appendix 4), the increased incidences of leukemias were responsible for the early deaths observed in male and female rats exposed to perchloroethylene. At autopsy, most of the leukemias were determined to be in an advanced and probably fatal stage. Because of the effect of the leukemias on the early mortality of the exposed rats, a life-table analysis was used to test for the statistical significance of the findings; this analysis revealed that the increased incidence of leukemia was statistically significant in both low- and high-dose male rats and in low-dose female rats, and was marginally significant ($p = 0.053$) in high-dose female rats.

Male rats also developed a significant increase in renal tubular cell adenomas and carcinomas. Perchloroethylene induced a significantly increased incidence of hepatocellular carcinomas at both dose levels in mice of both sexes. The NTP Peer Review Panel concluded that there was "clear evidence of carcinogenicity of tetrachloroethylene" (perchloroethylene) in male rats and in male and female mice, and "some evidence" in female rats (Ex. 8-31, Appendix 4; Ex. 1-0000, p. 11).

In addition, a number of human studies were submitted to the rulemaking record that implicate perchloroethylene as a potential carcinogen (Ex. 8-31). Among these was a study by Brown and Kaplan (1987/Ex. 8-31, Appendix 6), which reported a statistically significant elevation in urinary tract cancer deaths among 1,690 dry cleaning workers exposed to perchloroethylene and other petroleum solvents. However, a subcohort of workers who used perchloroethylene as the primary solvent showed no increase in bladder cancer mortality. Brown and Kaplan concluded that "confounding exposure to petroleum solvents complicates any conclusions regarding the association between [perchloroethylene] and cancer of the urinary tract" (Brown and Kaplan 1987/Ex. 8-31, Appendix 6, p. 540).

Katz and Jowett (1981/Ex. 8-31, Appendix 9) studied the mortality pattern of 671 female dry cleaning workers for the period 1963 through 1977. Elevated incidences of cancers of the kidney and genitals were reported, along with a smaller excess of bladder and skin cancers and lymphosarcomas. The authors concluded that, although results obtained with the methodology used (proportionate mortality ratios) require careful interpretation, "this study raises the possibility that exposure to dry cleaning fluids may increase the risk of certain cancers" (Katz and Jowett 1981/Ex. 8-31, Appendix 9, p. 510). The dry cleaning fluids used by members of the cohort included carbon tetrachloride, trichloroethylene, and perchloroethylene.

Steinhagen et al. (1983/Ex. 8-31, Appendix 8) reported a significant excess of liver cancer among male workers in the laundry and dry cleaning industry in New Jersey. This study was a retrospective case-control study. The liver cancer cases were concentrated among individuals who processed clothes and were exposed to chemicals. The report did not identify the solvents in use (Steinhagen, Slade, Altman, and Bill 1983/Ex. 8-31, Appendix 8).

Duh and Asal (1984/Ex. 8-31, Appendix 7) examined the mortality experience of 440 dry cleaning workers in Oklahoma for the period 1975 through 1981. Elevated standardized mortality odds ratios (SMORs) were found for both lung cancer (SMOR = 1.7) and kidney cancer (SMOR = 3.8) (Duh and Asal 1984/Ex. 8-31, Appendix 7).

Eric Frumin of the Amalgamated Clothing and Textile Workers Union (ACTWU) submitted a quantitative risk assessment conducted by Dr. Dale Hattis of the Center for Technology Policy and Industrial Development at the Massachusetts Institute of Technology (Hattis 1986/Ex. 8-31, Appendix 11-A). This work was conducted in 1986 for the National Institute for Environmental Health Sciences. Dr. Hattis used a pharmacokinetic model that incorporated species-specific rates of formation for the metabolites of perchloroethylene. Using the rat leukemia and mouse liver tumor data from the NTP (1986b/Ex. 8-31, Appendix 4) bioassay, Dr. Hattis obtained a "best estimate" of the lifetime cancer risk (for workers exposed at the former 100-ppm OSHA limit for 45 years to perchloroethylene) of 45 deaths per 1,000 workers. The plausible upper limit at this level of exposure was 650 per 1,000 workers. The best-estimate lifetime risks associated with 45 years of exposure to 50 or 10 ppm of perchloroethylene were 27 and 6.4 deaths per 1,000 workers, respectively (the upper-confidence limits were 420 and 110 deaths per 1,000 workers, respectively). The ACTWU asserted that the studies reviewed above provide "overwhelming" evidence that perchloroethylene is a potential human carcinogen, and urged OSHA to establish a PEL lower than the proposed 50-ppm limit.

In its posthearing comments, the Halogenated Solvents Industry Alliance (HSIA) (Ex. 186) discussed several aspects of the data on perchloroethylene to support its contention that perchloroethylene should not be considered a probable human carcinogen. Specifically, the HSIA pointed out the following:

- Brown and Kaplan (1987/Ex. 8-31, Appendix 6) found no increased evidence of cancer among a subcohort of workers exposed only to perchloroethylene and not to other dry cleaning solvents.

- Both EPA and IARC have determined the human evidence on the carcinogenicity of perchloroethylene to be "inadequate."

- The National Research Council of the National Academy of Sciences concluded that the results of the NCI gavage study (NCI 1977c) should be interpreted with caution because of the large doses administered, early mortality of the treated animals, and observed nephrotoxicity.

- Regarding the NTP inhalation bioassay (NTP 1986b), the EPA Science Advisory Board (SAB) determined that the incidence of rat leukemia was not related to perchloroethylene exposure, and that the development of male rat kidney tumors was brought about by a mechanism unique to male rats.

- The EPA SAB stated that the mouse liver tumors observed in both the gavage (NCI 1977c) and inhalation (NTP 1986b) bioassays arose as a result of perchloroethylene-induced peroxisomal proliferation, a mechanism specific to rodents.

OSHA does not agree with the HSIA's interpretation of the meaning of the points raised by this group. First, the authors of the Brown and Kaplan (1987/Ex. 8-31,

Appendix 6) study themselves pointed to the difficulty of establishing a definitive link between a particular solvent and an increased incidence of cancer in workers in the dry cleaning industry. For example, in the case of the group exposed to perchloro-ethylene only, the number of workers in the cohort was so small that even two or three exposure-related deaths in the perchloro-ethylene-only group would have caused a drastic swing in the SMR for bladder cancer in this subcohort. Thus, OSHA does not find that this study demonstrates the noncarcinogenicity of perchloroethylene.

As to the HSIA's second point, that neither the EPA nor IARC found the evidence for the carcinogenicity of perchloroethylene in humans adequate, OSHA notes that such evidence exists only for a handful of carcinogens (e.g., asbestos, benzene, vinyl chloride, arsenic), and that the overwhelming number of substances recognized as posing carcinogenic risks to workers have been determined to be carcinogenic on the basis of results in animals only. OSHA also believes that the regulation of many substances that have been designated as potential human carcinogens on the basis of clear evidence of their carcinogenicity in animals has undoubtedly contributed to the lack of evidence in humans by preventing overexposures to these substances in the workplace, and thus preventing cancer among these workers. Therefore, OSHA believes it appropriate and prudent to reduce workplace exposures to substances that have caused cancer in animals, especially when the animal studies are well-designed and carefully conducted bioassays.

The HSIA's third point, that the NCI gavage bioassay (NCI 1977c) has limitations, is irrelevant in the context of this discussion because OSHA is not relying on this bioassay to establish an appropriate limit for perchloroethylene.

The fourth point raised by the HSIA was that the Science Advisory Board of the EPA has questioned the relevance for human cancer risk of some of the tumors seen in the NTP (1986b/Ex. 8-31, Appendix 4) inhalation bioassay. OSHA believes that an explanation of the nature of the SAB's concern will demonstrate that an interpretation of the meaning of these data is a matter of professional judgment on which expert scientists themselves can differ. The SAB noted that there is some uncertainty regarding the significance of the leukemias observed in the perchloroethylene-exposed rats in the NTP (1986b/Ex. 8-31, Appendix 4) inhalation bioassay because the control rats in another NTP bioassay (NTP 1986c, the bioassay for methylene chloride) showed the same incidence of leukemias as the perchloroethylene-exposed rats (Ex. 186, pp. 6–7). However, OSHA points out that the independent peer review panel appointed by the NTP to evaluate the strength of the evidence for the carcinogenicity of perchloroethylene also considered the appropriateness of including the rat leukemia data when weighing the evidence for the carcinogenicity of perchloroethylene; the NTP panel concluded that the NTP (1986b/Ex. 8-31, Appendix 4) bioassay presented "clear evidence" of perchloroethylene's carcinogenicity in male rats (Ex. 8-31, Appendix 4, pp. 14-15). Thus, different scientists or groups of experts may interpret the same data differently; in this case, OSHA is not prepared to dismiss out-of-hand the leukemia data, given that leukemia contributed significantly to excess mortality in the perchloroethylene-exposed groups (NTP 1986b/Ex. 8-31, Appendix 4). The HSIA also questioned the relevance of the kidney tumors in male rats found in the NTP (1986b) bioassay. OSHA agrees with the SAB that these tumors may not be good predictors of human risk; however, the Hattis (1986/Ex. 8-31, Appendix 11-A) risk assessment did not use the rat kidney tumor data, and, in addition, OSHA is not relying on these findings to set the final rule's limit for perchloroethylene.

On the HSIA's fifth point, the significance of rat liver tumors as predictors of human cancer risk, OSHA notes that the SAB did not believe it appropriate to disregard the findings in the recent NTP (1986b/Ex. 8-31, Appendix 4) bioassay of perchloroethylene-dose-related increases in the incidence of liver tumors in mice. In a letter dated to EPA Administrator Lee Thomas in March 1988 (Ex. 186D), the SAB concluded:

> The Board's consensus on the significance of mouse liver tumors is that mechanistic explanations are not sufficiently well developed and validated at this

time to change EPA's present approach expressed in its risk assessment guidelines for carcinogenicity. It concludes that the generation of mouse liver tumors by chemicals is an important predictor of potential risks to humans (Ex. 186D, p. 2).

Based on the expert opinion of the NTP Peer Review panel and the EPA SAB, OSHA finds that the NCI (1986b/Ex. 8-31, Appendix 4) inhalation bioassay rat leukemia and mouse liver tumor data, which form the basis for the perchloroethylene quantitative risk assessment performed by Dr. Hattis (1986/Ex. 8-31, Appendix 11-A), should be regarded at this time as being relevant to the determination of potential human cancer risk from exposure to perchloroethylene in the workplace. The use of the rat leukemia data for the risk assessment may, however, add additional uncertainty to the risk estimates.

When EPA's Science Advisory Board considered perchloroethylene in January of 1987 (Ex./186C), it designated this substance as a Category C substance (i.e., a possible human carcinogen). However, in a letter to EPA Administrator Lee Thomas in March of 1988 (Ex. 186D), the SAB concluded that the overall weight of evidence for perchloroethylene "lies on the continuum between categories B2 [probable human carcinogen] and C." The SAB also stated that

> the distinction between the B2 and C categories can be an arbitrary distinction on a continuum of weight of evidence. The "black-white interpretation"...is indeed troubling.... A substance classified as [Category] C...for which human exposure is high may represent a much greater potential threat to human health [than substances classified as Category B2, B1, or A].
>
> EPA and other agencies...may, therefore, wish to take steps to reduce high exposures to substances in the C category whenever there appears to be a potentially significant threat to human health.... Indoor exposures to perchloroethylene, such as might be found in dry cleaning establishments not using the equivalent of good industrial hygiene practices, could merit action under this criteria. So might high levels of exposure to other solvents...that have been considered by the public as "safe" in the absence of sufficient evidence of carcinogenicity in animals. In many in-stances, this appearance of safety results from not yet having the results from well-designed bioassays such as those conducted by the National Toxicology Program.

OSHA agrees with the SAB that perchloroethylene is a substance that meets several of the criteria regarded by the SAB as meriting regulatory action. First, current exposures to perchloroethylene are high, often reaching the levels permitted by OSHA's existing PEL of 100 ppm. Second, several hundred thousand employees are regularly exposed to this widely used solvent. Third, the Hattis (1986/Ex. 8-31, Appendix 11-A) quantitative risk assessment suggests that a high cancer risk may be associated with exposure to perchloroethylene at OSHA's former or proposed PELs, indicating that exposures should be reduced to levels below the proposed 50-ppm level. Finally, the evidence for the carcinogenicity of perchloroethylene, which is briefly summarized below, is convincing.

The NTP (1986b/Ex. 8-31, Appendix 4) has concluded that perchloroethylene is carcinogenic by inhalation in both rats and mice. Based predominantly on the animal data, NIOSH has also concluded that perchloroethylene is a potential human carcinogen; NIOSH judged the evidence for perchloroethylene's carcinogenicity sufficient to warrant a separate 6(b) rulemaking (Ex. 8-47, Table N6B). In 1987, the International Agency for Research on Cancer (IARC) also classified perchloroethylene as a Category 2B carcinogen (i.e., a substance for which the evidence in animals is sufficient). The EPA's SAB has determined that perchloroethylene is a Category C carcinogen (i.e., a possible human carcinogen, and a carcinogen in animals). In addition, a number of human studies suggest elevated cancer risks, particularly of the kidney and bladder, among workers exposed to perchloroethylene and other solvents in dry cleaning facilities. Based on a review of all of the available evidence on perchloroethylene, including the testimony and briefs submitted by the parties, OSHA has determined that perchloroethylene is a potential human carcinogen that presents a significant risk of material health impairment to workers exposed to it in their places of work. This view was shared by several parties commenting in the record, including the Amalgamated Clothing and Textile Workers Union (Ex. 192), the AFL-CIO (Ex. 194), the American Public Health Association (Ex. 151), and NIOSH (Ex. 8-47).

The risk assessment conducted by Hattis (1986/Ex. 8-31, Appendix 11-A) estimates that there is an excess lifetime cancer mortality risk of 45 deaths per 1,000 workers exposed for 45 years to the current 100-ppm TWA PEL. Clearly, this high risk of mortality represents a significant risk. At the proposed level of 50 ppm, Dr. Hattis estimated the excess lifetime risk to be 27 deaths per 1,000 workers. OSHA concludes that this assessment and the underlying evidence clearly indicate that a further reduction in the PEL is necessary.

OSHA's analysis of the technological feasibility of reducing perchloroethylene exposures in affected industries, particularly in the dry cleaning industry, demonstrates that a PEL of 25 ppm is achievable using engineering and work practice controls; however, OSHA does not believe that information in the record at the present time demonstrates that it is feasible to reduce exposures to lower levels (see Section VII). In the dry cleaning industry, newer equipment, such as dry-to-dry dry cleaning machines, can achieve 25 ppm with engineering and work practice controls. This is true of smaller as well as larger operations.

The industry is gradually replacing older equipment with newer equipment, and a significant percentage of operations, including smaller operations, have installed such equipment. According to the industry, dry cleaning equipment is replaced at approximately 10-year intervals.

OSHA is providing a four-year phase-in period for the industry to come into compliance with the new levels through the use of engineering controls. Accordingly, OSHA believes that both smaller and larger dry cleaning operations can achieve the new 25-ppm TWA level in the ordinary course of the equipment replacement schedule. Consequently, the economic impact of the change to new equipment would not be great even for smaller operations.

In addition, use of older equipment in good condition results in employee exposure levels not much above the new 25-ppm PEL. Industry estimates indicate that levels of approximately 40 ppm can be attained. During the four-year interval noted in this regulation, reasonably priced retrofits for older equipment may be developed that can be used to achieve the 25-ppm PEL.

OSHA is, of course, sympathetic to the circumstances of small businesses. If, after three years following publication of this regulation, it appears that there will be significant economic impacts for small dry cleaning operations attempting to convert to new equipment or retrofit within the four years permitted by the standard, OSHA will consider extending the period for smaller dry cleaning operations to achieve compliance using engineering and work practice controls. If that situation develops, OSHA believes that a trade association petition bringing the facts to OSHA's attention would be appropriate. OSHA would, at that time, evaluate the available information and make a decision based on all the information obtainable.

OSHA is establishing in the final rule a revised 8-hour TWA PEL of 25 ppm for perchloroethylene. OSHA concludes that the revised limit will substantially reduce the significant risk of material impairment of health presented by exposure to this substance at the Agency's former PEL of 100 ppm.

APPENDIX C - CALCULATIONS FOR ECONOMIC ANALYSIS (DRY CLEANING)

Line-by-line Explanation of Economic Analysis and Inventory Calculations for Dry Cleaning Facility

Note: The model dry cleaning facility to be analyzed uses a 50-lb., dry-to-dry, closed-loop machine with a refrigerated condenser. Except as noted, the data used to analyze the model dry cleaning facility has been taken directly from a U.S. EPA report titled "Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process."

General Data Regarding Model Facility

1. Average annual revenue of the model facility is $260,000. While EPA acknowledges that the average annual revenues of dry cleaners varied widely, the EPA felt that $260,000 a year assumption would represent a typical, successful dry cleaner. The EPA derived the exact figure after discussions with industry groups, equipment manufacturers and distributors, and dry cleaners.[1]

2. Base price for dry cleaning a suit or full garment is $7.17 per garment. This represents the cost to clean a full suit (or two half garments such as a jacket and pair of pants).[2]

3. Based on the first two assumptions, the model facility will clean 36,262.2 garments per year. ($260,000/year/$7.17/garment = 36,262.2 garments per year.) This translates into 697.35 garments per week.

4. Each garment is assumed to weigh an average of 2.205 lbs. Thus, the facility cleans an average of (697.35 x 2.205 =) 1,538 lbs of clothes per week or 79,958.2 pounds of clothes per year.

5. Assuming the dry cleaner is running the 50-lb. machine at 90 percent of capacity, the average load cleaned will be 45 pounds. In order to clean 1,538 pounds of clothes per week, the cleaner will need to run (1538 / 45 =) 35 loads per week.

6. 35 loads per 5 day work week implies that 7 loads are cleaned per day. Assuming that each load runs for 45 minutes, then the dry cleaning machine is in use for 5.25 hours per day.

General Formulas

Capital expenditures are annualized using a Capital Recovery Factor (CRF). The formula used for the CRF is:

$CRF = [i\,(1+i)^n] / [((1+i)^n)-1]$
  i = the interest rate
  n= the estimated useful life of the equipment

The following chart shows the calculated CRF for a discount rate (i) of 7 percent and varying estimated useful livespans in years of the capital (n).

n=10	CRF=0.142378
n=15	CRF=0.109795
n=17.5	CRF=0.100871
n=20	CRF=0.094393
n=25	CRF=0.085811
n=30	CRF=0.080586

Note: The sample economic analysis below will always assume a discount rate of 7 percent, as used by the EPA in their report. The EPA chose 7 percent as the appropriate private discount rate based on the document "Guidance on the Preparation of Economic Analysis and Regulatory Impact Analysis in OPPT."[3] However, the accompanying chart will include economic analysis performed using discount rates of 5%, 6%, 7%, 8%, and 9%. Use of multiple discount rates allows the reader to analyze how sensitive the results of the economic analysis are to assumptions about the discount rate.

Cost of Operating Model Dry Cleaning Facility

Yearly Receipts:	$260,000	
Cleaning Costs	$7.17	per garment
# Garments Cleaned	36262.2	per year
	697.35	per week
Garment weight	2.21	lbs.
Lbs. Clothes Cleaned	79958.2	per year
	1537.7	per week
Loads per week	35	
Loads per day	7	
Machine Use	5.25	hours per day

Capital Recovery Factor for Selected Discount Rates, Useful Lives

	Discount Rate				
Useful Life	5%	6%	7%	8%	9%
10	12.95%	13.59%	14.24%	14.90%	15.58%
15	9.63%	10.30%	10.98%	11.68%	12.41%
17.5	8.71%	9.39%	10.09%	10.81%	11.56%
20	8.02%	8.72%	9.44%	10.19%	10.95%
25	7:10%	7.82%	8.58%	9.37%	10.18%
30	6.51%	7.26%	8.06%	8.88%	9.73%

Cost Categories	Cost		i=5%	i=6%	i=7%	i=8%	i=9%
1. Capital Cost - 50 lb. Dry Clean Machine	$45,347		$4,369	$4,669	$4,979	$5,298	$5,626
2. Maintenance & Energy Costs			$1,422	$1,422	$1,422	$1,422	$1,422
3. Capital Cost - Refrigerated Chiller	$6,921		$896	$940	$985	$1,031	$1,078
4. Maintenance & Energy Costs			$501	$501	$501	$501	$501
5. Capital Cost - Aerocooling Unit	$2,100		$169	$183	$198	$214	$230
6. Maintenance & Energy Costs			$32	$32	$32	$32	$32
7. Spotting Board with Steam Gun	$1,507		$145	$155	$165	$176	$187
8. Vacuum Pump & Compressor	$2,255		$217	$232	$248	$263	$280
9. Capital Costs - 20 HP Boiler	$9,350		$814	$878	$943	$1,011	$1,081
10. Maintenance			$150	$150	$150	$150	$150
11. Capital Cost - Pressing Equipment	$15,987		$1,540	$1,646	$1,755	$1,868	$1,983
12. Maintenance			$1,890	$1,890	$1,890	$1,890	$1,890
13. Start Up Costs	$52,945		$3,444	$3,846	$4,267	$4,703	$5,153
14. Initial Fill-Up of Perc	$5.20	per gallon of perc	$54	$61	$67	$74	$81
15. Haz. Waste Disposal Start-Up Fee	$146		$9	$11	$12	$13	$14
16. Perc Use	$5.20	per gallon of perc	$762	$762	$762	$762	$762
17. Charging Detergent	$21	per gallon of detergent	$1,679	$1,679	$1,679	$1,679	$1,679
18. Spotting Chemicals			$686	$686	$686	$686	$686
19. Filter Replacement	$163	every 7,800 lbs	$1,676	$1,676	$1,676	$1,676	$1,676
20. Bags &	$34	per 535 bags	$604	$604	$604	$604	$604
21. Hangers			$1,593	$1,593	$1,593	$1,593	$1,593
22. Water Utilities	1.01	% of sales	$2,626	$2,626	$2,626	$2,626	$2,626
23. Electric Utilities	1.15	% of sales	$1,930	$1,930	$1,930	$1,930	$1,930
24. Fuel	1.76	% of sales	$4,576	$4,576	$4,576	$4,576	$4,576
25. Labor benefits	3.50	% of sales	$9,100	$9,100	$9,100	$9,100	$9,100
26. Labor			$98,997	$98,997	$98,997	$98,997	$98,997
27. Insurance (labor)	16.50	% of labor	$16,334	$16,334	$16,334	$16,334	$16,334
28. Separator Water Disposal	$71	per 13.5 gallons	$684	$684	$684	$684	$684
29. Filter Disposal	$25	per filter	$2,050	$2,050	$2,050	$2,050	$2,050
30. Still Bottom Disposal	$71	per 13.5 gallons	$841	$841	$841	$841	$841
31. Operation and Management Costs	30.90	% of sales	$80,340	$80,340	$80,340	$80,340	$80,340
Total Costs			$240,132	$241,095	$242,093	$243,125	$244,187

C. Line-By-Line Analysis

1. Capital Cost - The EPA's economic analysis estimated that the average capital cost of a dry cleaning machine is $45,346.88 (including a 5 percent sales tax).[4] This estimate is based on the average sales prices of four different models of dry cleaning machines. The models are all 50-lb dry-to-dry closed-loop machines with refrigerated condensers, stills, and either spin disk or cartridge filters. The capital cost is annualized over an estimated 15-year useful life to obtain an annual capital cost of $4,978.85 per year. Using the CRF with n=15 and i=7%, the annual capital cost is:

Annual Capital Cost = CRF (n=15, i=7%) x Purchase Cost
= 0.109795 x ($45,346.88)
= $4,978.85 per year

2. Maintenance and Energy Consumption for Dry Clean Machine- The EPA estimated maintenance costs for the dry cleaning machine to average $745/year. These costs included $360 per year for labor and $385 per year for machine parts.

Electricity consumption is based on the assumption that the electrical specifications of the dry cleaning machines are 28.75 amps at 230 volts. It is assumed that each load takes 45 minutes. Thus, cleaning 35 loads per week will require the dry cleaning machines to be used for 26.25 hours. Finally, electricity is assumed to cost $0.075 per kilowatt hour (kWh). Energy costs are calculated as follows:

(28,75 amps) x (230 volts) x (26.25 hrs./week) x (1 kilowatt/ 1000 volts x amps) x (52 weeks/yr.) = 9,026.16 kWh per year

(9,026 kWh/yr.) x ($0.075/kWh) = $677 per year.

Adding maintenance and energy costs gives a total cost of $1,422.[5]

3. Capital Cost for the Refrigerated Condenser - The EPA report assumes that the capital cost of the refrigerated condenser is $6,921.34 (including a 5 percent sales tax). The refrigerated condenser is assumed to have a ten year useful life.[6]

Annual Capital Cost = CRF (n=10, i=7%) x Purchase Cost
= 0.142377 x $6,921.34
= $985.44 per year

4. Maintenance and Energy Consumption for Refrigerated Condenser - Based on an estimate provided by District Cleaners Equipment of Washington, DC, the EPA assumed an annual maintenance cost of $150 for the refrigerated condenser.

The electrical specification of the average refrigerated condenser is assumed to be 33 amps at 208 volts. The condenser is assumed to operate whenever the dry cleaning machine is in use, or for 5.25 hours per day. However, the condenser is only needed for 26 weeks, from May through October, when the temperature is warm. Energy costs are:

(33 amps) x (208 volts) x (5.25 hrs/wk) x (1 kilowatt/ 1000 volts x amps)
= 36.036 kWh per day
(36.036 kWh/day) x (5 days/wk) x (26 weeks/yr.) = 4,685.2 kWh./yr.

(4,685.2 kWh/yr.) x ($0.075/kWh) = $351.35 per year.

Adding maintenance and energy costs gives a total cost of $501.35.[7]

5. Capital Cost of Aerocooling Unit - During the cooler parts of the year, the larger refrigerated condenser is not needed. Instead, a smaller aerocooling unit is used which requires considerably less energy. Based on a purchase price of $2,100 (including a 5 percent sales tax) and a useful life of 20 years, the annual cost of the aerocooling unit is:[8]

Annual Capital Cost	= CRF (n=20, i=7%) x Purchase Cost
	= 0.094393 x $2,100
	= $198.23

6. Maintenance and Energy Consumption of the Aerocooling Unit - The maintenance cost of the unit is assumed to be negligible. The unit is assumed to be run at 3 amps at 208 volts whenever the machine is in use (5.25 hours per day) from November through April (26 weeks).[9]

(3 amps) x (208 volts) x (5.25 hrs./day) x (1 kilowatt/ 1000 volts x amps)
= 3.276 kWh/day
(3.276 kWh/day) x (5 days/wk) x(26 weeks/year) = 425.1 kWh/year

(425.1 kWh/yr.) x ($0.075/kWh) = $31.94/year.

7. Capital Cost of Spotting Board with Steam Gun - The spotting board and steam gun are essential to the spotting process. The application of steam is used to remove water soluble stains and to kill bacteria.[10] The capital cost of a spotting board with steam gun is $1506.75. The useful life of the equipment is estimated at 15 years. Thus, the annual capital cost for this equipment is:[11]

Annual Capital Cost	= CRF (n=15, i=7%) x Purchase Cost
	= 0.109795 x $1,506.75
	= $165.43

8. Capital Cost of Vacuum Pump and Compressor - $2,255 will be needed to purchase an air compressor ($1309) and a 5 h.p. vacuum pump ($946). The useful life of the equipment is estimated at 15 years. The annual capital cost for this equipment is:[12]

Annual Capital Cost	= CRF (n=15, i=7%) x Purchase Cost
	= 0.109795 x $2,255
	= $247.59

9. Capital Cost for 20 HP Boiler - A boiler is needed to generate steam for spotting, for heating the dry cleaning machine, and for pressing. EPA estimated the capital cost for a twenty horsepower boiler to be $9,350, with a useful life of 17.5 years.[13]

Annual Capital Cost	= CRF (n=17.5, i=7%) x Purchase Cost
	= 0.100871 x $9350
	= $943.14

10. Boiler Maintenance - Based on an estimate from the Fulton Boiler Works, the EPA assumed annual maintenance costs for any size boiler to be $150 per year.[14]

11. Capital Cost of Pressing Equipment - Pressing equipment is used in both wet and dry cleaning systems to finish clothes. Pressing is used to remove wrinkles and, if necessary, any remaining stains. The following pressing equipment will be required:[15]

Utility Presser with Steam Iron Attachment	$ 4,645
Pants Topper	2,100
Legger with Steam Iron Attachment	5,590
Three-Way Puff Iron	931
Steam Finisher	1,960
Total	$15,226

Adding a 5 percent sales tax brings the total cost of the pressing equipment to $15,987.30. Assuming a useful life of 15 years, the annual cost is calculated at:

Annual Capital Cost = CRF (n=15, i=7%) x Purchase Cost
= 0.109795 x $15,987.30
= $1755.32

12. Pressing Equipment Maintenance - Maintenance for the pressing equipment is estimated to cost 10 percent of the list price for each piece of equipment. Thus, annual maintenance costs for pressing equipment are estimated at $1,890.[16]

13. Start Up Costs - Certain capital expenditures are required to simply open a professional clothes cleaning establishment. Costs include expenditures to make necessary adjustments to the physical property, to purchase equipment to process and store garments. Additionally, an initial expenditure is needed to buy necessary supply of cleaning and business materials. All costs are annualized over a thirty year period. Start up costs for a dry cleaner include:[17]

Installation and Rigging (electrical, gas, water, etc.)	$16,500.00
Lease Hold Improvements (construction, decoration, cash register, etc.)	20,000.00
Signage	5,000.00
Initial Inventory of Supplied	4,000.00
Bagging Rack	103.95
Scale Cart	244.65
6 Bu Basket	76.65
8 Bu Basket	85.05
Slick Rails	1,365.00
800 Slot Conveyer	5,569.75
Total	$52,945.05

Start Up Costs (annualized) = CRF (n=30, i=7%) x Purchase Cost
= 0.080586 x $52,945.05
= $4,266.65

14. Initial Fill-Up of Perc - To operate a new dry cleaning machine will require a one-time only purchase of perc to fill the machine to capacity. After this initial fill, perc will be added a little bit at a time as required by the amount of cleaning done. The average capacity for a 50-lb. dry-to-dry closed-loop machine is estimated at 161 gallons. Using an assumed cost of $5.20 per gallon of perc, the original purchase of perc will cost $837.20. Annualizing this over thirty years yields the following annual cost:[18]

Start-Up Costs (annualized) = CRF (n=30, i=7%) x Purchase Cost
= 0.080586 x $837.20
= $67.47

15. Hazardous Waste Disposal Start-Up Fee - Hazardous waste disposal costs are based on information EPA obtained from Safety-Kleen. Safety-Kleen is the most commonly used company for disposing of filter cartridges, still residues, and other perc-contaminated wastes from the dry cleaning industry. A one time fee is imposed by Safety-Kleen to become a customer and have the company dispose of hazardous waste. The fee is assumed at $146 and is annualized over 30 years.[19] This start-up fee is in addition to the price Safety-Kleen charges, per drum, for actual perc disposal.

Start-Up Costs (annualized) = CRF (n=30, i=7%) x Purchase Cost
= 0.080586 x $146
= $11.77

16. Perc Use - The cost of perc use is calculated using the assumption that 30,000 pounds of clothes can be cleaned per 55 gallon drum of perc. Our model cleaner is assumed to clean 79,958.2 pounds of clothes per year. The annual cost of perc usage is:[20]

79,958.2 lbs. clothes/year x (55 gallons perc/30,000 lbs. clothes) = 146.6 gallons/year

(146.6 gallons/yr.) x ($5.20/gallon) = $762.27/year

17. Charging Detergent - The cost of the charging detergent assumes that the cost of detergent is $21/gallon and that 1 percent of the cleaning solvent is charged detergent. The International Fabricare Institute recommends distilling 10 gallons of cleaning solvent per 100 pounds of clothes cleaned. Thus, to clean 79,958.2 pounds of clothes in one year will require distilling 7,996 gallons of charged solvent. Since 1 percent of the charged solvent is detergent, this amounts to using 79.97 gallons of detergent per year. At $20/gallon, this would cost $1,679.37.[21]

18. Spotting Chemicals - The annual cost of spotting chemicals is as follows:[22]

Ammonia	(2.45882 gallons used/year) x ($6.28 / gallons) =	$ 15.44/yr
Amyl Acetate	(1.32574 gallons used/year) x ($19.90 / gallons) =	26.38/yr
General Formula	(0.75920 gallons used/year) x ($46.20 / gallons) =	35.08/yr
Moisture Stock	(0.94042 gallons used/year) x ($16.75 / gallons) =	15.75/yr
Neutral Lubricant	(3.09269 gallons used/year) x ($16.75 / gallons) =	51.81/yr
Oil Type Paint Remover	(25.44438 gallons used/year) x ($20.95 / gallons) =	533.06/yr
Peroxide	(1.22382 gallons used/year) x ($6.70 / gallons) =	8.20/yr
Total Annual Cost of Spotting Chemicals		= $685.72/yr

19. Filter Replacement - A 50-lb dry cleaning machine is estimated to use 1 cartridge filter (with 6 carbon core filters per cartridge) and 2 double all carbon filters for every 7,800 lbs. of clothes cleaned. The cost of a cartridge filter is assumed to be $105.42, while the cost of 2 double all carbon filters is $58.06. Thus, the total cost of replacing all required filters is $163.48 and occurs after every 7,800 lbs. of clothes cleaned. To clean 79,958.2 pounds of clothes every year will require (79,958.2 / 7800) 10.25 replacements of all 8 machine filters. Total annual cost of filter replacements is calculated as:[23]

($163.48 / 7,800 lbs. of clothes) x (79,958.2 lbs. of clothes / year) = $1,675.84 / yr.

20. Purchase of Bags - One clear plastic bag is used per order. Based on an estimated average of 4 garments per order, the cleaner is using 9,065.55 bags per year (36,262.2 garments per year divided by 4). A role of 535 bags is assumed to cost \$33.95. Thus, the cost of bag usage is:[24]

(9,065.55 bags used / year) x (\$33.95 / 535 bags) = \$575.28 / yr. for bags

Adding a 5 percent sales tax brings the total annual cost of bags to \$604.05 / yr.

21. Purchase of Hangers - The cost of hangers is assumed at \$18.45 per box of 500 for suit hangers and at \$24.63 per box for women's apparel. An estimated 60 percent of garments use suit hangers, while the other 40 percent use hangers for women's apparel. Thus, the cost of providing hangers for the 36,262.2 garments cleaned per year is calculated as follows:[25]

(36,262.2 garments) x (60%) x (\$18.45 / 500 hangers) =	\$ 802.85 for suits
(36,262.2 garments) x (40%) x (\$24.63 / 500 hangers) =	714.51 for women's apparel
Total annual cost of hangers	= \$1,517.36 / yr.

Adding a 5 percent sales tax brings the total annual cost of hangers to \$1,593.22 / yr.

22. Water Utilities - The EPA Report assumed the water and sewer utilities to be 1.01 percent of the total annual sales of the dry cleaner.[26]

(1.01% x 260,000) = \$2,626.00

23. Electric Utilities - The EPA Report assumed the electric utilities to be 1.15 percent of the total annual sales of the dry cleaner. However, we must subtract out the cost already attributed to the dry clean machine, to the refrigerated chiller, and to the aerocooling unit. Thus, total energy costs are calculated as:[27]

(1.15% x \$260,000) - \$677.04 - \$351.35 - \$31.94 = \$1,929.75

24. Fuel - The EPA Report assumed the cost of fuel to be 1.76 percent of the total annual sales of the dry cleaner.[28]

(1.76% x \$260,000) = \$4,576.00

25. Insurance (Labor Excluded) - Includes fire insurance, insurance on customer goods and occupancy, as well as liability. Insurance is estimated at 3.5 percent of annual sales.[29]

(3.5% x \$260,000) = \$9,100

26. Labor - Total labor costs include the following:[30]

- Front counter help is assumed to work 120 hours per week, 52 weeks per year at \$5/hr.
  Thus, the total cost of front counter help is \$31,200.
- According to NCA, pressers are capable of finishing 8–16 garments per hour. This analysis will assume that the average presser can finish 12 garments per hour and is paid \$9 per hour. These two assumptions are equivalent to EPA's assumption that

pressing costs $0.75 per garment. Thus, to clean 36,262.2 garments per year would cost:

(36,262.2 garments) x (1 hour / 12 garments) x ($9 / 1 hour) = $27,196.65.

- A dry cleaning spotter is also needed for an estimated 6 hours per cleaning day (30 hours per week). At an estimated $10/hr., the annual cost of spotting labor is $15,600.
- The manager is assumed to earn $25,000 per year. The manager often performs the role of the spotter, in which case his salary would be $40,600 - the combined salary of the two workers.

Thus, the total cost of labor is: $31,200 + $27,196.65 + $15,600 +$25,000 = $98,996.65

27. Labor Benefits - Payroll taxes and insurance on labor are calculated at 16.5 percent of total labor costs.[31]

28. Separator Water Disposal - A 50-lb dry-to-dry closed-loop machine with refrigerated condenser is estimated to generate 0.5 gallons of water per day. Thus, 130 gallons of separator water are generated per year. According to Safety-Kleen, the cost of separator water disposal is $71 for a 13.5 gallon drum (which includes a $6 service for use of the specially designed drum). Thus, the annual cost of separator water disposal is:[32]

(130 gallons/year) x ($71 / 13.5 gallons) = $683.70 / year

29. Filter Disposal - Safety-Kleen reports that the cost for filter disposal is $23 per filter (including a $6 service for providing a specially designed drum for filter disposal and transportation). Since each drum can hold three filters, the service fee per filter is $2. Thus, the total cost of filter disposal is $25 per filter.

The EPA report assumes that dry cleaning machine filters will have to be replaced after every 7,800 pounds of clothes cleaned. From item #19, we calculated that cleaning 79,958.2 pounds of clothes every year will require (79,958.2 / 7800) 10.25 such replacements. Each replacement consists of 8 filters; 6 carbon core filters in the cartridge and 2 double all carbon filters. Thus, the dry cleaner must dispose of a total of (10.25 x 8) 82 filters per year. The total annual cost of filter disposal is calculated as:[33]

(10.25 filter replacements) x (8 filters / replacement) x ($25 disposal cost / filter) = $2050 / yr.

30. Still Bottom Disposal - An assumed 2 gallons of still bottoms are generated per 1,000 pounds of clothes cleaned. Disposal costs are $71 per 13.5 gallons (including a $6 service fee for the disposal drum). Thus, total still bottom disposal costs are estimated at:[34]

(79,958.2 lbs. of clothes) x (2 gallons / 1,000 lbs.) x ($71 / 13.5 gallons) = $841.04 / yr.

31. Operation and Management Costs - The EPA identified several other costs inherent to owning and operating a professional clothes cleaning shop, including:[35]

Building Rent/Overhead	9.36% of total receipts
Advertising	2.28% of total receipts
Ground/Building Works	9.05% of total receipts
Claims	0.34% of total receipts
Office Expenses	1.30% of total receipts
Administrative Expenses	1.56% of total receipts
Interest and Bank Charges	4.06% of total receipts
Miscellaneous	2.95% of total receipts
Total Operation and Management Costs	30.90% of total receipts

Thus, total operation and management costs are $80,340 per year.

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[1]U.S. EPA, *Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process,* EPA 744-R-93-004, (September 1993): 3-2.
[2]Ibid.
[3]Ibid., p. 3–4.
[4]Ibid., item #1 in Appendix IV.
[5]Ibid., items #2 and #3 in Appendix IV.
[6]Ibid., item #4 in Appendix IV.
[7]Ibid., items #5 and #6 in Appendix IV.
[8]Ibid., item #7 in Appendix IV.
[9]Ibid., items #8 and #9 in Appendix IV.
[10]Ibid., p. 1–7.
[11]Ibid., item #14 in Appendix IV.
[12]Ibid., items #20 and #21 in Appendix IV.
[13]Ibid., item #18 in Appendix IV.
[14]Ibid., item #19 in Appendix IV.
[15]Ibid., items #22–31 in Appendix IV.
[16]Ibid., items #22–31 in Appendix IV.
[17]Ibid., items #'s 32–35, 38–43 in Appendix IV.
[18]Ibid., item #36 in Appendix IV.
[19]Ibid., item #37 in Appendix IV.
[20]Ibid., item #44 in Appendix IV.
[21]Ibid., item #45 in Appendix IV.
[22]Ibid., items #47–56 in Appendix IV.
[23]Ibid., items #57–58 in Appendix IV.
[24]Ibid., item #59 in Appendix IV.
[25]Ibid., item #60 in Appendix IV.
[26]Ibid., item #61 in Appendix IV.
[27]Ibid., item #62 in Appendix IV.
[28]Ibid., item #63 in Appendix IV.
[29]Ibid., item #73 in Appendix IV.
[30]Ibid., items #64–66, and #68 in Appendix IV.
[31]Ibid., item #69 in Appendix IV.
[32]Ibid., item #70 in Appendix IV.
[33]Ibid., item #71 in Appendix IV.
[34]Ibid., item #72 in Appendix IV.
[35]Ibid., items #74–81 in Appendix IV.

APPENDIX D - CALCULATIONS FOR ECONOMIC ANALYSIS (WET CLEANING)

Line-by-Line Explanation of Economic Analysis of Wet Cleaning Facility

A. General Data Regarding Model Wet Cleaning Facility

The model wet cleaning facility is based on the use of a 50-lb. Aqua Clean Systems wet machine. Aqua Clean manufacturers recommend loading the machine to 50–60 percent capacity in order to minimize the effects of mechanical action on delicate garments. Assuming that the machine is run at 55 percent of capacity, each load will process 27.5 pounds of clothes. Given these load sizes, the manufacturer of the Aqua Clean System recommends the use of a 30-lb. Aqua Clean dryer with the Aqua Clean washer. Because the average drying cycle is only 11 minutes, the dryer can also be used to dry loads of clothes that are multiprocess wet cleaned.[1] The facility will clean approximately 70 percent of the garments using the Aqua Clean machine, while multiprocess wet cleaning will be used to process the remaining 30 percent of the garments.

The model facility, as in the dry clean example, cleans 79,958.2 pounds of clothes per year (1537.7 pounds per week). Based on the assumption 70 percent of the clothes are processed by wet machines, the model wet cleaning facility will use the Aqua Clean machine to clean 55,970.7 pounds of clothes per year (1076.4 pounds per week). Multiprocess wet cleaning will be used for the remaining 23,987.45 pounds of clothes (461.3 pounds per week). At 27.5 pounds cleaned per load in the Aqua Clean washer, the cleaner must wash 40 loads per 5 day work week.

Note: Prices contained in the EPA report "Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and an Alternative Process" are in 1992 dollars.[2] Since the majority of prices used in this analysis are in 1992 dollars, prices obtained for the wet clean machine, which are in 1994 dollars, will be converted into 1992 dollars. Using the most recent data for Price Deflators from the Council of Economic Advisers, we see that general prices rose from 121.1 in the third quarter of 1992 to 126.5 in the third quarter of 1994. That is, prices rose by 4.45912 percent during that two year stretch. To deflate 1994 prices to 1992 dollars all 1994 dollars figures are divided by 1.0445912.[3]

Cost of Operating Model Wet Cleaning Facility

Yearly Receipts:	$260,000	
Cleaning Costs	$7.17	per garment
# Garments Cleaned	36,262.2	per year
# Cleaned w/ Wet Machines (70%)	25,383.5	per year
# Cleaned w/Multiprocess Wet (30%)	10,878.7	per year
Garment weight	2.2	lbs.
Lbs. Clothes Cleaned	79,958.2	per year
	1,537.7	per week
Loads cleaned per week	40	
Loads dried per week	56	

Capital Recovery Factor for Selected Discount Rates, Useful Lives

	Discount Rate				
Useful Life	5.00%	6.00%	7.00%	8.00%	9.00%
6	19.70%	20.34%	20.98%	21.63%	22.29%
8	15.47%	16.10%	16.75%	17.40%	18.07%
10	12.95%	13.59%	14.24%	14.90%	15.58%
15	9.63%	10.30%	10.98%	11.68%	12.41%
16.5	9.04%	9.71%	10.41%	11.12%	11.86%
17.5	8.71%	9.39%	10.09%	10.81%	11.56%
20	8.02%	8.72%	9.44%	10.19%	10.95%
25	7.10%	7.82%	8.58%	9.37%	10.18%
30	6.51%	7.26%	8.06%	8.88%	9.73%

Cost Categories	Cost		i=5%	i=6%	i=7%	i=8%	i=9%
1. Capital Cost - 50 lb. Wet Machine and 30-lb dryer	$29,974		$2,888	$3,086	$3,291	$3,502	$3,719
2. Maintenance Costs	$313		$313	$313	$313	$313	$313
3. Energy Costs - Washer	$346		$346	$346	$346	$346	$346
4. Energy Costs - Dryer	$132		$132	$132	$132	$132	$132
5. Paint Spray Gun	$1,507		$145	$155	$165	$176	$187
6. Spotting Board with Steam Gun	$1,507		$145	$155	$165	$176	$187
7. Scrubbing Board w/ Industrial Sink	$263		$17	$19	$21	$23	$26
8. Vacuum Pump & Compressor	$2,255		$217	$232	$248	$263	$280
9. Capital Costs - 10 HP Boiler	$7,802		$679	$732	$787	$844	$902
10. Maintenance			$150	$150	$150	$150	$150
11. Capital Cost - Pressing Equipment	$15,987		$1,540	$1,646	$1,755	$1,868	$1,983
12. Maintenance			$1,890	$1,890	$1,890	$1,890	$1,890
13. Start Up Costs	$52,700		$3,428	$3,829	$4,247	$4,681	$5,130
14. Wet Machine Detergent	$12.74	per gallon of detergent	$1,713	$1,713	$1,713	$1,713	$1,713
15. Wet Machine Sizing	$14.99	per gallon of sizing	$4,031	$4,031	$4,031	$4,031	$4,031
16. Spotting Chemicals			$686	$686	$686	$686	$686
17. Bags &	$34	per 535 bags	$604	$604	$604	$604	$604
18. Hangers			$1,593	$1,593	$1,593	$1,593	$1,593
19. Water Utilities			$3,031	$3,031	$3,031	$3,031	$3,031
20. Electric Utilities			$1,930	$1,930	$1,930	$1,930	$1,930
21. Fuel	1.76	% of sales	$4,576	$4,576	$4,576	$4,576	$4,576
22. Insurance (non-labor)	3.50	% of sales	$9,100	$9,100	$9,100	$9,100	$9,100
23. Labor			$102,826	$102,826	$102,826	$102,826	$102,826
24. Labor Benefits	16.50	% of labor	$16,966	$16,966	$16,966	$16,966	$16,966
25. Operation and Management Costs	30.90	% of sales	$80,340	$80,340	$80,340	$80,340	$80,340
Total Costs			$239,287	$240,082	$240,907	$241,760	$242,640

B. Line-By-Line Analysis

1. Capital Cost for Aqua Clean Systems Washer and Dryer - The purchase price of a 50-lb. capacity Aqua Clean washer (the FLE220 FC System 50 Washer) and a 30-lb. capacity Aqua Clean Dryer (the TT270 RMC System 30 Dryer) is $29,820. Deflating this to 1992 dollars brings the purchase price to $28,547. Adding a 5 percent sales tax increases the purchase cost to $29,974. Aqua Clean manufacturers estimate that the useful life of the machine will be similar to the useful life of other Wascomat washing machines, which have an average lifetime of 15 to 18 years.[4] Assuming a useful life of 15 years, the annual capital cost of the machines is calculated as:

Annual Capital Cost = CRF (n=15, i=7%) x Purchase Cost
= (0.109795) x $29,974
= $3,291 per year

2. Maintenance for Aqua Clean Washer and Dryer - According to the Aqua Clean manufacturer, the system is basically maintenance-free. However, in the absence of more precise estimates, the maintenance will be assumed at 1% of the capital cost. Based on this assumption, the annual maintenance cost for the Aqua Clean System washer and dryer will be 1% x $31,311 = $313.11 per year.

3. Energy Consumption for Aqua Clean Washer - Electricity consumption for the washer is based on the assumption that the electrical specifications of the wet cleaning machines are 20 amps at 220 volts.[5] Further, it is assumed that each load takes 30 minutes.[6] Thus, cleaning 40 loads per week will require the wet cleaning machines to be used for 20 hours per week. Finally, electricity is assumed to cost $0.075 per kWh. Energy costs for the Aqua Clean washer are calculated as follows:

(20 amps) x (220 volts) x (20 hrs./week) x (1 kilowatt/ 1,000 volts x amps)
x (52 weeks/yr.) = 4,576 kWh hours per year

(4,576 kWh/yr.) x ($0.075/kWh) = $346.32 per year.

4. Energy Consumption for Aqua Clean Dryer - The dryer is used to clean 79,958.16 lbs. of clothes each year. Assuming each load is 27.5 pounds (the average load cleaned in the washer), a total of 56 loads will be dried each week. The electrical specifications of the dryer are 15 amps at 220 volts.[7] According to the Aqua Clean System manufacturer, the average drying cycle takes 10–12 minutes.[8] Based on an average drying cycle of 11 minutes, 56 loads will require the dryer to be in use for 10.27 hours per week. Finally, electricity is assumed to cost $0.075 per kWh. Energy costs for the Aqua Clean dryer are calculated as follows:

(15 amps) x (220 volts) x (10.27 hrs./week) x (1 kilowatt/ 1,000 volts x amps)
x (52 weeks/yr.) = 1,762.33 kWh per year

(1,762.33 kWh/yr.) x ($0.075/kWh hr.) = $132.17 per year.

Note: For garments that are not fully immersed in water during cleaning (such as steam cleaning), the estimated drying time of 11 minutes per load is high. Thus, we may be overestimating actual energy use in the dryers.

5. Capital Costs for Spotting Board with Steam Gun and Paint Spray Gun - Beyond the wet machine and dryer, additional capital needed for multiprocess wet cleaning include a spotting board with steam gun, a paint-spray steam gun, an industrial sink, and a scrubbing board. From item #7 in the dry cleaning line-by-line analysis (Appendix C), we assumed that the cost of the scrubbing board with steam gun is $165.43 per year. This is based on a purchase price of $1,506.75 and a useful life of 15 years. In the absence of data, the capital cost for the paint spray gun will be assumed to be similar to that of the steam gun.

6. Capital Cost for Scrubbing Board with Industrial Sink - The capital cost of a the scrubbing board with industrial sink is $262.50. The useful life of the equipment is estimated at 30 years. Thus, the annual capital cost for this equipment is:

Annual Capital Cost = CRF (n=30, i=7%) x Purchase Cost
= 0.0805864 x $262.50
= $21.15

7. Capital Cost of Vacuum Pump and Compressor - same as for dry cleaning. See item #8 of Appendix C.

8. Capital Cost for 20 HP Boiler - Aqua Clean manufacturers state that use of a 8 HP boiler is standard with their washer and dryer. However, this may vary if the boiler is used for other purposes.[9] A larger boiler may be needed to provide steam for multiprocess wet cleaning. Thus, we will assume that our model facility uses a 20 HP boiler. The capital cost for a twenty horsepower boiler for wet cleaning is assumed to be $9,350, with a useful life of 17.5 years.[10]

Annual Capital Cost = CRF (n=17.5, i=7%) x Purchase Cost
= 0.100871 x $9350
= $943.14

9. Boiler Maintenance - same as for dry cleaning. See item #10 from dry cleaning line-by-line analysis.

10. Capital Cost of Pressing Equipment - same as for dry cleaning. See item #11 from dry cleaning line-by-line analysis.

11. Pressing Equipment Maintenance - same as for dry cleaning. See item #12 from dry cleaning line-by-line analysis.

12. Start-Up Costs - Same as for dry cleaning (See item #13 from dry cleaning line-by-line analysis), except that the scale cart is not purchased. The cost of the scale cart, $244.65, is thus removed from the total start up costs. This brings the total start-up costs to $52,700.40. Annualizing these costs over 30 years yields the following:

Annual Start-Up Costs = CRF (n=30, i=7%) x Purchase Cost
= 0.080586 x $52,700.40
= $4,246.94

13. Wet Machine Detergent - For use with their washers, Aqua Clean Systems, Inc. markets the detergent Aquasafe. According to its manufacturer, the detergent is biodegradable as well as being a highly active, pH-neutral product. The detergent also contains water soluble, protein based collagen additives which penetrate the capillaries of natural fibers to eliminate swelling, felting, and shrinkage. Aqua Clean Systems, Inc. markets Aquasafe detergent at $13.31 per gallon, and recommends that 20 ml of the detergent are used per kilo of clothes cleaned.[11] Adjusting the detergent cost to 1992 dollars yield a cost of $12.74/gallon.

20 ml / 1 kilo = 0.02 liters / kilo x 1 gallon / 3.785 liters x 1 kilo / 2.2 pounds
= 0.02 gallons of detergent per 8.326 lbs.

To estimate detergent use per 100 pounds of clothes, we solve the following ratio

0.02 gallons / 8.327 pounds = x gallons / 100 pounds
x = 0.2402 gallons per 100 pounds.

Thus, to clean 55,970.71 pounds of clothes with Aquasafe detergent will cost:
55,970.71 lbs. x (0.2402 gallons / 100 lbs) x ($12.74 / gallon) = $1,712.79

14. Wet Machine Sizing - Along with the special detergent, Aqua Clean manufacturers recommend use of special Prefinish sizing, which contains a higher concentration of protein-based collagen along with natural and synthetic polymers. The Prefinish is injected into the washer during the final rinse cycle in order to reduce the amount of retained water in clothes for the subsequent drying process. Aqua Clean manufactures recommend using 40 ml of Prefinish sizing per kilo of clothes cleaned. Prefinish sizing retails for $15.66 per gallon.[12] Adjusting to 1992 dollars, the cost of Prefinish sizing is $14.99 per gallon.

40 ml / 1 kilo = 0.02 liters / kilo x 1 gallon / 3.785 liters x 1 kilo / 2.2 pounds of clothes
= 0.04 gallons of detergent per 8.327 lbs of clothes

To estimate detergent use per 100 pounds of clothes, we solve the following ratio

0.04 gallons / 8.327lbs. clothes = x gallons / 100 pounds
x = 0.4804 gallons per 100 pounds of clothes

Thus, to clean 55,970.71 pounds of clothes with Prefinish sizing will cost:
55,970.71 lbs x (0.4804 gallons / 100 lbs) x ($14.99 / gallon) = $4,210.71

15. Spotting Chemicals for Multiprocess Wet Cleaning - In the absence of firm data about spotting chemical usage for wet machines, we shall assume that the wet facility spends $686 per year on spotting chemicals. This does not seem unrealistic. According to the EPA report, the cost of spotting in multiprocess wet cleaning is more expensive than spotting for dry cleaning. However, spotting for clothes to be cleaned in wet machines is likely to be less expensive because cleaners needed spot water-based stains. The ambiguous effect of these two factors causes us to assume that the wet facility will spend as much as a dry cleaning facility for spotting chemical use.

16. Purchase of Bags - same as for dry cleaning. See item #20 from dry cleaning line-by-line analysis.

17. Purchase of Hangers - same as for dry cleaning. See item #21 from dry cleaning line-by-line analysis.

18. Water Utilities - The EPA Report assumed the water and sewer utilities for a dry cleaner to be 1.01% of the total annual sales of the dry cleaner, or $2,262. Water use is predominantly for pressing and spotting - activities that are not specific to dry cleaning. Dry cleaning specific activities such as water for the detergent charge and water for the refrigerated chiller were negligible (costing $0.19 and $0.04 respectively in the EPA report). Thus, the whole $2,262 cost will be attributed to pressing and spotting.[13]

According to manufacturers, water use by the Aqua Clean washer is roughly 100 gallons per load[14]. Thus , cleaning 40 loads per week will use the following amount of water:

(40 loads/week) x (100 gallons/load) x 52 weeks/year = 208,000 gallons/year

Richard Simon, of the former EcoClean International, estimated that in multiprocess wet cleaning roughly 20% of clothes (excluding shirts) are fully immersed in water. Data collected by EPA closely matches this estimate. Water usage for this cleaning was estimated at 40 gallons per 18 pounds of clothes cleaned. Although these estimates are based on cleaning in a home washing machine, they are the only available usage rates and will be used.[15] (Note: more accurate water use figures are forthcoming from a demonstration project by Environment Canada). Thus, water use for fully immersed clothes in multiprocess wet cleaning is:

23,987.45 lbs. clothes x 20% x (40 gallons / 18 lbs.) = 10,661 gallons per year

In the EPA report, Richard Simon was also cited as estimating that 10 gallons of water are used for every 100 garments that are not fully immersed in water.[16] Thus, for the 10,878.66 garments that are wet cleaned, water use is:

(36,262.2 garment/yr.) x (30% of garments are wet cleaned) x (80% of garments are not fully immersed in water) x (10 gallons / 100 garments) = 870 gallons/yr

Thus, the total water consumption specific to wet cleaning is 219,531 gallons. At a cost of $2.62/100 ft^3, the cost this water is:

(219,531 gallons) x (231 in^3/gal) x (ft^3/12 in^3) x ($2.62/100 ft^3)= $768.89

Adding $2262, we find that the total cost of water and sewer utilities for a wet cleaner is estimated at $3031.

19. Electric Utilities - From item #23 in the dry cleaning line-by-line analysis, the total cost of electricity not attributed directly to cleaning itself is $1,929.75 per year.

20. Fuel - The EPA Report assumed the cost of fuel to be 1.76% of the total annual sales of the dry cleaner ($4,576). In the absence of data about fuel use in wet facilities, the annual costs of fuel will be assumed to be equal for both a wet and dry cleaner.

21. Insurance (Labor Excluded) - same as for dry cleaning. See item #27 from dry cleaning line-by-line analysis.

22. Labor -

- Front counter help is assumed to work 120 hours per week, 52 weeks per year at \$5/hr.
  Thus, the total cost of front counter help is \$31,200.

  (120 hours/week) x (52 weeks/year) x (\$5/hour) = \$31,200.00/year

- According to NCA, average pressing rates range from 8 garments per hour to as high as 16 garments per hour.[17] The cost of pressing labor is assumed at \$9 per hour. Given concerns that wet cleaning requires longer processing time, we will base our labor costs for wet cleaning on a low pressing rate - 9 garments per hour - compared to 12 garments per hour for dry cleaning (Note: a further discussion of labor costs is included in the section on sensitivity analysis). Yearly labor costs are calculated as

  (36,262.2 garments / year) x (1 hour / 9 garments) x (\$9 / hour) = \$36,262.20/year

- For spotting in the wet cleaning facility, less labor is required because the spotter does not need to spot water-based stains that will be cleaned in the wet machine. Whereas dry cleaning spotting is assumed at 45 minutes per 45 lb. load, spotting for machines will be assumed at 35 minutes per 45 lbs. of clothes. Thus, to clean 1,537.66 lbs. of clothes per week in machines will require roughly 20 hours of spotting. The total annual cost of labor for machine wet spotting would then be:

  (1,537.66 lbs./week) x (52 weeks/year) x (0.5833 hours/45 lbs) x (\$10 / hr.)
  = \$10,364/year

- The manager is assumed to earn \$25,000 per year.

Thus, total labor costs are: \$31,200 + \$36,262 + \$10,364 + \$25,000 = \$102,826

23. Insurance (Labor) - Payroll taxes and insurance on labor are calculated at 16.5% of total labor costs.

24. Operation and Management Costs - same as for dry cleaning. See item #27 from dry cleaning line-by-line analysis.

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[1]Personal communication with Kevin Daly, Product Manager, Aqua Clean Systems, Inc., January 3, 1995.
[2]U.S. EPA, *Multiprocess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process*, EPA 744-R-93-004, (September 1993). See, for example, Exhibit 2.1 on page 2-16 which displays dry clean machine costs in 1992 dollars.
[3]U.S. Council of Economic Advisors, "Economic Indicators for November 1994," p. 2.
[4]Daly 1995.
[5]Aqua Clean Systems, Inc., "Aqua Clean: The Environmentally Safe Alternative to Dry Cleaning," Fact sheet, p. 2 under "Aqua Clean System Technical Specifications."
[6]Daly 1995.
[7]Aqua Cleaning Systems, Inc., p. 2 under "Aqua Clean System Technical Specifications."
[8]Daly 1995.
[9]Ibid.
[10]U.S. EPA, *Multiprocess Wet Cleaning* 1993, item #18 in Appendix IV
[11]Aqua Clean Systems Inc., fact sheet on dealer prices for Aquasafe Detergent, Prefinish Sizing, and Suedesoft, (dated effective October 1, 1994).
[12]Ibid.

[13]U.S. EPA, *Multiprocess Wet Cleaning* 1993. See Model Cleaning Facility Profile: Line by Line Description of Line 61.
[14]Daly 1995.
[15]U.S. EPA, *Multiprocess Wet Cleaning* 1 993. See Model Cleaning Facility Profile: Line by Line Description of Lines 61.
[16]Ibid.
[17]Ibid., Description of Lines 65.

APPENDIX E - REGULATORY INFORMATION

TABLE 20 - REGULATIONS SUMMARY

The following is a table which summarizes process vent control standards for dry cleaning machines.[1]

[1]Michigan Department of Commerce and Natural Resources, Fact Sheet #9306, "What Dry Cleaners Should Know About the Clean Air Act", (Lansing, MI: Small Business Clean Air Assistance Program, Environmental Services Division, 1994): 4–5.

Existing Installed before Dec. 9, 1991	New Installed between Dec. 9, 1991, and Sept. 22, 1993	New Installed after Sept. 22, 1993
	MAJOR SOURCE	
Dry-to Dry By 9/23/96, the air-PCE stream from the machine shall be routed through a refrigerated condenser or carbon adsorber if the adsorber was installed prior to 9/22/93 [63.322(a)(1) or (a)(2)]. **Transfer** By 9/23/96, the air-PCE stream from the washer and dryer shall be routed through refrigerated condensers or a carbon adsorber if the adsorber was installed prior to 9/22/93 [63.322(a)(1) or (a)(2)]. The washer and dryer must also be contained in an enclosure maintained under negative pressure and controlled by a separate carbon adsorber [63.322(a)(3) & 63.322(h)(1)(2)].	**Dry-to Dry** By 9/22/93, the air-PCE stream within the machine shall be routed through a refrigerated condenser or carbon adsorber if the adsorber was installed prior to 9/22/93 . By 9/23/96, the air-PCE stream within the machine shall be routed through a refrigerated condenser [63.322(b)(1)] and the air-PCE stream remaining in the machine at the end of the dry-cleaning cycle shall be vented to a supplemental carbon adsorber before the machine door is opened or immediately upon door opening [63.322(b)(3)]. **Transfer** By 9/22/93, the air-PCE stream within the washer and dryer shall be routed through refrigerated condensers or a carbon adsorber if the adsorber was installed prior to 9/22/93. By 9/23/96, the transfer machine system must be taken out of service [63.322(b)(2)].	**Dry-to-Dry** Immediately upon installation, the air-PCE stream within the machine shall be routed through a refrigerated condenser [63.322(b)(1)] and the air-PCE stream remaining in the machine at the end of the dry cleaning cycle shall be vented to a supplemental carbon adsorber before the machine door is opened or immediately upon door opening [63.322(b)(3)] **Transfer** Banned [63.322(b)(2)]
	LARGE AREA SOURCE	
Dry-to Dry By 9/23/96, the air-PCE stream from the machine shall be routed through a refrigerated condenser or carbon adsorber if the adsorber was installed prior to 9/22/93 [63.322(a)(1) or (a)(2)]. **Transfer** By 9/23/96, the air-PCE stream from the dryer and washer shall be routed through refrigerated condensers or a carbon adsorber if the adsorber was installed prior to 9/22/93 [63.322(a)(1) or (a)(2)].	**Dry-to Dry** By 9/23/93, the air-PCE stream from the machine shall be routed through a refrigerated condenser or carbon adsorber if the adsorber was installed prior to 9/22/93. By 9/23/96, the air-PCE stream within the machine shall be routed through a refrigerated condenser. **Transfer** By 9/22/93, the air-PCE stream from the dryer and washer shall be routed through refrigerated condensers or a carbon adsorber if the adsorber was installed prior to 9/22/93. By 9/23/96, the transfer machine system must be taken out of service [63.322(b)(2)].	**Dry-to-Dry** Upon installation of the machine, the air-PCE stream from the machine shall be routed through a refrigerated condenser [63.322(b)(1)]. **Transfer** Banned [63.322(b)(2)]
	SMALL AREA SOURCE	
Dry-to-Dry No control is required. **Transfer** No control is required.	**Dry-to Dry** By 9/23/93, the air-PCE stream from the machine shall be routed through a refrigerated condenser or carbon adsorber if the adsorber was installed prior to 9/22/93. By 9/23/96, the air-PCE stream from the machine shall be vented through a refrigerated condenser. **Transfer** By 9/22/93, the air-PCE stream from the dryer and washer shall be routed through refrigerated condensers or a carbon adsorber if the adsorber was installed prior to 9/22/93. By 9/23/96, the transfer machine system must be taken out of service [63.322(b)(2)].	**Dry-to-Dry** Upon installation of the machine, the air-PCE stream from the machine shall be routed through a refrigerated condenser [63.322(b)(1)]. **Transfer** Banned.

APPENDIX F - WET CLEANING INFORMATION

TABLE 21 - WET CLEANING PERCENTAGES

Summary of the Range of Percentages of Clothes that Can Be Wet Cleaned
As Reported by Wet Cleaning Practitioners

Organization	% can be cleaned by wet machine	% not machine washable, but can be done by multiprocess wet	% can be cleaned by perc only, not wet
Wascomat (Distributors of Aqua Clean Wet Machines)[1]	up to 70%, but recommends 40–60% to be cautious	not addressed	not addressed
Ecomat[2] (A private wet cleaner)	80% is currently being cleaned by machines	20% is cleaned using multiprocess wet	0%
Neighborhood Cleaner Association[3] (Perc cleaners association)	25–35% total wet, no breakdown for machine v. multi-process		65 – 75%
Environment Canada[4] (Governmental agency testing wet cleaning)	70%	25%	5%

[1]Aqua Cleaning Systems, Inc., fact sheet titled "Aqua Clean: The Environmentally Safe Alternative to Dry Cleaning."
[2]Personal communication with Diane Weiser, CEO & President of EcoFranchising, Inc., January 3, 1995.
[3]Personal communication with William Seitz, Executive Director, Neighborhood Cleaners Association, January 3, 1995.
[4]Personal Communication with Toby Brodkorb, Engineer, Environment Canada, December 12, 1994.

APPENDIX G - SURVEY RESULTS FOR DRY CLEANING

In a small survey of Chicago residents who use dry cleaners done by C&R Research Services and commissioned by the Center for Neighborhood Technology, dry cleaning customers repeatedly ranked performance issues as an important characteristic of dry cleaners. On a scale from 1 (not important) to 7 (very important), "clothes look good", "clothes feel fresh" and "stain or spot removal" received average rankings over 6.5.[1] Partial results of the survey are summarized in Table 7.

TABLE 22 - SURVEY RESULTS RATING IMPORTANCE OF PERFORMANCE ISSUES[2]

Characteristic of Dry Cleaner	Percentage of Responses above 5 [1 (not important) to 7 (very important)]	Average Score
"Clothes Look Good"	97%	6.69
"Clothes Feel Fresh"	94	6.53
"Stain or Spot Removal"	95	6.53

[1]C&R Research Services, Dry Cleaning Project, #8957, Survey Performed for the Center for Neighborhood Technology (November 1994).
[2]C&R Research Services 1994.

APPENDIX H - WET CLEANING MACHINE INFORMATION

Summary Wet Cleaning Machine Technology and Manufacturers

The following is a draft report summarizing wet cleaning machines. This report was compiled by the Center for Neighborhood Technology and reprinted with their permission.

WET CLEAN MACHINES

Center For Neighborhood Technology
by Cynthia Vasquez
March 28, 1995

DRAFT

Wet cleaning holds tremendous promise for the garment profession, the consumer, and the environment. The term wet cleaning encompasses several types of alternative cleaning processes, one being wet cleaning by machines. Wet clean machines are a new line of commercial washing and drying machines that can accommodate "dry-clean-only" garments by: reducing agitation during washing, increasing extraction of water prior to drying, using specifically formulated wet cleaning soaps and spotting agents, and closely monitoring heat and moisture content during the drying process. The Center for Neighborhood Technology recently compiled information on the features and costs of the wet clean machines which are available on the market today. The findings are summarized below.

There are several companies which sell and distribute wet clean machines/systems. They include:

1. Unimac Commercial Laundry Equipment
   Unimac Company, Inc.
   3595 Industrial Park Drive
   Marianna, Florida 32446-9458
   Ph: 904-526-3405
   Fax: 904-526-1509
   Contact: Tom Fleck

2. Aqua Clean Systems, Inc.
   469 Doughty Boulevard
   P.O. Box 960338
   Inwood, NY 11096-0338
   Ph: 516-371-4404 ext. 118
   Fax: 516-371-4204
   Contact: Neal Milch

3. IPSO, USA
   P.O. Box 497
   LaFayette Hill, PA 19444
   Ph: 1-800-USA-IPSO
   Fax: 610-828-7199
   Contact: Bob Isenberg/Dirk Laceur
   Note This machine will not be available on the U.S. market until mid to late 1995.

4. Miele Professional Products Group
   22D Worlds Fair Drive
   Somerset, NJ 00899
   Ph: 800-843-7231
   Fax: 908-560-7469
   Contact: Denis O'Brien
   NOTE This machine will not be available in the U.S. market until late 1995.

5. Fashion Ace Equipment Supply Co., Inc.
514 Warren Blvd.
Bromall, Pa. 19008
Ph: 610-353-6707
Contact: Hyok Su Kwon

* Note * This document does not provide information about the Fashion Wet Cleaning System, which was used in the wet clean demonstration study, "The Green Clean Project", conducted by Environment Canada. One of the shops involved in the project used it, with good results. Unfortunately, despite many repeated attempts, CNT was unable to obtain information from the distributor/manufacturer regarding their system. However, Environment Canada was quoted a price of $5,600 which includes temperature controlled Fashion Wet Clean Wash basins and a small extraction unit. This quote was for delivery by Canadian suppliers to the "Green Clean Project", and is subject to change.

Disclaimer 1: This document is not an evaluation of the wet clean machines mentioned in this report. It does not attempt to make a qualitative judgement on any of the wet clean machines reviewed- it is strictly a compilation of information obtained from each company featured.

Disclaimer 2: The costs of the machines featured in this document are costs obtained by industry reps in January 1995. They are subject to change without notice.

Wet Clean Machines

X = Optional feature

	Aqua Clean 30S,30G,50S,50G (Made in Sweden)	Unimac UF230W and UF160W (Made in US)	Miele WS 5190 TR (Made in Germany)	IPSO HFC 145,234,304 (Made in Belgium)
Washer-Extractor Features				
• Load capacity	30 and 50 lbs	30 and 50 lbs	22 lbs (wet clean) 42 lbs. (wash)	30, 50, and 70 lbs.
• Extract G force	30 lb- 40-310 G 50 lb- 40-300 G	30 lb- up to 345 G 50 lb- up to 345 G	125-460 G	120-140 G
• Drum RPMs	30 lb- 24-950 RPM 50 lb- 24-850 RPM	30 lb- 46-960 RPM 50 lb- 44-960 RPM	43 (wash) 300-1100 (spin)	10-50 RPM(wash) 250- 1000 RPM(spin)
• Frequency controlled motor	Yes	Yes	Yes	Yes
• Programmable microprocessor	Yes	Yes	No-computer controlled parameters can be adjusted	Yes
no. of programs	up to 90	up to 46	7 wet clean, 16 wash	up to 39
• Longest wash cycle	35 mins (Avg 30 mins.)	40 mins	75 min.	up to 99 mins. (Avg. 15 mins.)
• Steam heat direct or indirect	Yes Indirect	Yes Direct Indirect(X)	Yes Indirect	Yes Direct
• Gas heat	No	No	No	No
• Electric Heat	No	Yes(X)	Yes	Yes(X)

	Aqua Clean 30S,30G,50S,50G (Made in Sweden)	**Unimac** UF230W and UF160W (Made in US)	**Miele** WS 5190 TR (Made in Germany)	**IPSO** HFC 145,234,304 (Made in Belgium)
Washer-Extractor Features (con't)				
• No. of soap/chemical dispensers	up to 5	2 or 5	7	up to 5
• Auto. spray thru door for waterproofing/flame retardant of garments	Yes	Yes(X)	Yes	Yes
• Low level/empty tank alarm	Yes	Yes(X)	Yes	Yes
• No. of recycling tanks for water/chemicals	1	1 or 2(X)	0	1(X)
• No. of peristaltic pumps	2	2 or 3(X)	3	up to 5
• Pump/filter recirculation system	Yes	Yes(X)	Yes	Yes(X)
• Soaps/Detergents brand names used	Aquasafe Detergent, Prefinish Sizing and Suedsoft-BUFA	Recommend BUFA, Sietz chemicals Unimac does not sell the soaps themselves. Contact chemical co.'s directly	Kreussler, BUFA	BUFA, Sietz
cost/gallon	$13.31, $15.66, and $17.98 respectively	Dependent upon supplier	Dependent upon supplier	Dependent upon suppl

Drying Machines

	Aqua Clean 30S,30G,50S,50G	Unimac 50CSHP,75CSHP	Miele T 6550 TR	American Dryer ADS50, ADS75
Dryer Features				
• Load capacity	30 and 50 lbs	50 and 75 lbs	22 lbs (wet clean) 31 lbs (wash)	50 and 75lbs.
• Steam heated	Yes	Yes	Yes	Yes
• Gas heated	Yes (X)	No	No	Yes(X)
• Electric heated	No	Yes(X)	Yes	Yes(X)
• Drying cycles	Avg.- 20 mins. (dependent upon load size)	Light loads-8-15 mins. Average- approx. 25 mins. Heavy loads- 35 mins.	10 to 40 mins	Light loads- 5-15 mins. Avg. loads- 10-15 mins.
• Programmable drying and temp times	Yes	Yes	Yes	Yes
• Humidity control	Residual Moisture Control sensor	Internal moisture sensor (temp. based)	Residual Moisture Control Sensor	Internal Moisture sensor (temp. based)
• Anti-wrinkle feature	Yes	Yes	No info	Yes
• Special features	"Package" includes soaps, detergents spotting chemicals available thru Aqua Clean	Steam damper system on 75 lb load capacity dryer	Thermometer displays temp. inside drum, air recycling	Digital controls, displays temp and % dryness or time remaining

Equipment Costs

Brand Name	Cost
AQUA CLEAN	
ACS30G (30 lb. capacity steam heated washer and gas heated dryer)	$25,782
ACS30S (30 lb. capacity steam heated washer and steam heated dryer)	$26,367
ACS50G (50 lb. capacity steam heated washer and gas heated dryer)	$34,590
ACS50S (50 lb. capacity steam heated washer and steam heated dryer)	$37,395
OPTIONS:	
No real "options" per se Aqua clean sells their systems in "package" form	

Equipment Costs

Brand Name	Cost	
UNIMAC		
UA160W (35 lb. capacity direct steam heated washer-extractor)	$11,081	
UA230W (50 lb. capacity direct steam heated washer extractor)	$13,658	
50CSHP (50 lb. capacity steam heated dryer)	$2,889	
75CSHP (75 lb. capacity steam heated dryer)	$3,269	
WASHER OPTIONS:	**UA160**	**UA230**
Indirect steam heating	$1043	$1043
Spray thru the door	$978	$978
Chemical pump Cart (or can get from chemical co.)	$1733	$1733
Empty Tank alarm	$761	$761
Electric heating option	$549	$702
Micro-process simulator		
Inverter drive programmar	No info	No info
DRYER OPTIONS:	**50CSHP**	**75CSHP**
Stainless Steel Front	$350	$400
Stainless Steel Cylinder	$380	$420
Microcomputer controls (for internal sensor)	$170	$170
Automatic reverse agitator	$700	$700

Equipment Costs

Brand Name	Cost
MIELE	
MIELE WS 5190 TR	
42 lb. electric washer	$32,000
42 lb. steam heated washer	$33,000
MIELE T 6550 TR	
31 lb. electric dryer	$8,500
31 lb. steam heated dryer	$10,000
OPTIONS:	
No information at press time	

Equipment Costs

Brand Name	Cost
IPSO	
HF145 (30 lb. washer-extractor)	$13,930
HF234 (50 lb. washer-extractor)	$16,473
HF304 (75 lb. washer-extractor)	$21,075
OPTIONS:	
Chemical pumps mounted to the side of the washer (typically 4)	$267 ea.
Second drain valve	$492
External pump	$165
AMERICAN DRYER	
ADS30 Dryer (30 lb.)	$2,715
ADS50 Dryer (50 lb.)	$3,100
ADS75 Dryer (75 lb.)	$3,430

THE AQUA CLEAN SYSTEM (30S,30G,50S,50G)

This system is made by Electrolux\Wascomat in Sweden. It is distributed by Aqua Clean Systems, Inc. in the United States.

Washer Features

* 30 lb. and 50 lb. maximum machine capacity (1)

* High Spin Washer Extractor- Extract G force for 30 lb. washer: 40-310 G, for 50 lb. washer: 40-300G. Drum RPM - 30 lb. washer: 24-950 RPM, 50 lb. washer: 24-850 RPM.

* Has a frequency controlled motor, which allows operator to change speeds/mechanical action of the drum quickly and efficiently.

* Programmable microprocessor can create, store, and retrieve up to 90 programs.

* Average wash cycle is 30 minutes, while the longest wash cycle is 35 mins.

* Washers are only available with indirect steam heat. Indirect steam heat is an essential feature on a wet cleaning machine because it prevents "hot spots" from forming in the cylinder.

* Can automatically dispense up to seven liquid soaps/chemicals, five for the washing process, two for the wet cleaning process. Has through-the-door automatic spray for waterproofing or flame retarding of garments.

* Low level water tank alarm

* 1 tank for water or chemical recycling

* 2 peristaltic pumps

* The soaps/chemicals that the Aqua Clean System uses are BUFA soaps/chemicals, which they have renamed for distribution with the Aqua Clean system within the United States. According to Aqua Clean, they are completely biodegradable, and approved for disposal in a sanitary sewer system. Aquasafe Detergent, Prefinish Sizing, and Suedesoft suede and leather cleaner are BUFA soaps Oldopal Basic, Oldopal Prefinish, and Bufalicker EW, respectively.

(1) = In wet cleaning systems, load capacity in practice depends upon whether operator is doing wet cleaning, wet washing (i.e. reg. laundry), shirt laundry, or leather and suede cleaning. For those articles which are highly sensitive to mechanical action, (i.e. angora and wool), actual load capacity is only 50% of the stated maximum machine capacity.

* Spotting agents from Aqua Clean will be on the market by April 1995. Like their soaps, Aqua Clean's spotting agents "contain no EPA-regulated chemicals, eliminating the need for hazardous waste disposal." They include Biotol for blood and albumin stains; Tanol for coffee, tea, wine, and related stains; Color for oil and grease-based organic stains; Tintol for ink stains; and Rostol for rust and metal stains. Exact pricing has not been fixed yet, but according to a company representative, these spotting agents will be priced comparably to dry-side spotting chemicals.

* Recycling tank is separate from machine, and can be attached either on the side of the machine or placed underneath the machine.

Dryer Features

* Load capacity: 30 lb. and 50 lb.

* Offers both steam and gas heated models- gas is less expensive

* 20 minutes average drying cycle (dependent upon load size)

* Programmable drying and temp. times

* Residual Moisture Control (RMC): This monitor measures garment humidity directly - meaning it actually monitors the humidity of the garments themselves inside the drum. According to Aqua Clean, the RMC measures humidity of the garments 400 times per second, and the dryer automatically stops once the desired humidity is met. According to Aqua Clean, other dryers which claim to sense humidity ("moisture control") have a sensor which monitors the humidity in the dryer exhaust air (which is accurate only to +/-21%), not in the garments themselves. Aqua Clean claims their RMC feature is a much more sensitive and exact monitor (accurate to +/- 2%), than these "moisture control" types of dryer monitors.

Misc.

* Aqua Clean sells their systems in the "package form": they provide you not only with the washer and dryer, but also with needed accessories, i.e. soaps, spotting chemicals, etc. When an Aqua Clean system is purchased, a representative of the company will visit the shop and provide consulting services for shop set up, as well as a price quote for installation. Aqua Clean can then do the installation. (It may also be possible to find a local distributor who will do the installation at a cheaper rate- be sure to check around first!). Aqua Clean will provide on-site training (cost included in purchase price) for the system once the shop is set up, machines installed, employees hired, etc; 1 to 2 days of training should be sufficient. Product support and technical information are available by phone. Low-cost financing for credit-worthy buyers is also available.

THE UNIMAC UA160W AND UA230W WET CLEANING SYSTEMS

This system is made in Marianna, Florida.

Washer-Extractor Features

* 30 lb. and 50 lb maximum machine capacity

* High speed washer extractor- Extract G-force maximum: 345 G's Drum RPM range- UF160W (30lb.): 46RPM-960 RPM, UF230W (50 lb.): 44 RPM-960RPM

* Microcomputer abilities: 39 field programmable cycles, 7 programmable wash actions, 3 programmable water levels, 2 programmable wash speeds, 4 programmable extract options, 7 liquid supply signals, programmable heat option (indirect steam or electric), temperature readout.

* Wash cycles: shortest cycle time for delicate clothes is approx. 15 minutes. Longest cycle time for clothes that are heavily soiled and waterproofed, approx. 40 minutes.

* Direct steam heat is a standard feature (part of the original Unimac washer-extractor design). Indirect steam heating is a wet clean "option". As mentioned previously, in order to get even heating and no "hot spots" inside the drum, indirect steam heating must be used for wet cleaning.

• Can automatically dispense up to 5 types of liquid soaps/chemicals for washing process. These dispensers are not part of the machine, but are attached to it on the side and kept on a separate chemical cart. Through-the-door spraying for waterproofing or flame retarding of garments is another wet clean optional feature.

* Empty tank alarm -this alarm can also function as a low level alarm. You can adjust it to any level you want.

* Unimac offers single and double built-in tanks for water/chemical reuse. (Water re-use is not recommended for wet cleaning, since there is a tendency for the water to become contaminated by fibers, dirt, etc., during the washing cycle.)

* Choice of 2 or 3 peristaltic pumps. These are used for pumping the soaps/chemicals from the dispensers.

* Unimac does not directly sell the soaps/chemicals or pumps for their systems. You would need to purchase the soaps from the companies which make them, or through a local distributor who is knowledgeable in this area. Unimac recommends soaps such as those sold by BUFA and/or Caled to use with their system.

* Unimac offers as an option a stainless steel freestanding supply dispensing cart. Traditionally, dispensing equipment and support is provided on a no charge basis by the chemical supplier as long as the customer purchases the products from the supplier. Purchasing dispensing equipment may be necessary if your chemical supplier does not provide dispensing support with their products.

* According to Unimac, their washer-extractors already had many of the important wet clean features on them; the options have been added on as they've learned more about perfecting the machine wet clean process.

Dryer Features (50CSHP, 75CSHP)

* 50 and 75 lb. load capacity- only Unimac offers a 75 lb. dryer.

* Steam or electric heating is recommended for even heating, eliminating hot spots associated with gas fired dryers. With steam heating requires a clean, dry, regulated 80 psi air supply.

* Programmable microcomputer controls: Microprocessor control allows variables such as time, temperature, moisture retention, and cool down to be programmed to the exact needs of the wet clean process. Five standard drying cycles are available for normal drying and five additional custom cycles can be programmed to meet the needs of wet cleaning. All 10 drying cycles can be customized. According to a company representative, Unimac has established pre-set drying cycles which reflect the optimum blend of parameters to match the type of load/garments in the dryer.

* Average drying cycle is 26 minutes. For lighter loads, anywhere from 8-15 minutes. For heavier loads, around 35 minutes.

* Reversing cylinder: Helps prevent tangling during the drying cycle. Tangling causes uneven drying results and longer tumbling times. A feature for long items whose length exceed the diameter measurement of the cylinder(i.e. wedding gown).

Misc

* Unimac's factory trained and authorized distributor in the Chicago area is Haiges Machinery, Inc. They can provide installation at your request. The prices for the equipment is F.O.B. factory. Haiges is responsible for on-site warranty and start up training. Their Chicago phone number is: 708-669-3300.

<u>The Miele WS 5190TR and T 6550TR Wet Cleaning System</u>

This system is made in Germany.

<u>Washer Features</u>

* 42 lb.maximum machine capacity

* Extract G-force: 125-460G

* Drum RPM's: 43 RPM (wash)
  300-1100 RPM (spin)

* This system has a frequency controlled monitor.

* The washer does not have a programmable microprocessor. According to a company representative, "The new system will not have a programmable computer, but a computer control with pre-set programs. The user will be able to adjust certain parameters, i.e. temperatures. These permanent programs reflect the experience in wet cleaning Miele has collected during the last 5 years in Europe, and will be not only easier to use, but also more error-proof than a programmable unit."

* There are 16 different pre-set wash programs, and 7 wet clean ones.

* The longest wash cycle is 75 minutes.

* Indirect steam heat is a standard feature. Electric heat is offered, but gas heat is not.

* The washer has up to 7 soap/chemical dispensers. Has standard through-the-door automatic spray for waterproofing of garments.

* Has a standard low level/empty tank alarm.

* There are no recycling tanks for water and chemicals. Miele does not offer this because they don't think its necessary for wet cleaning, and also because it is "not economical."

* The washer has 3 peristaltic pumps and a pump/filter recirculation system.

* Information is not available as to whether Miele will be selling any soaps\chemicals themselves. At this point, they recommend "any Miele approved chemicals," i.e. Seitz or BUFA.

Dryer Features

* Load capacity- 31 lbs.(wash), 22 lbs.(wet clean)

* Offer both steam and electric heated models. The electric version is less expensive. (Please refer to Appendix B for equipment costs). Miele does not offer a gas heated model.

* Drying cycles range from 10-40 mins.

* Programmable drying and temperature times.

* Automatic reverse agitator action

* Residual Moisture Control Sensor (RMC): This is the same type of sensor which is used in the Aqua Clean System Dryer. It measures the residual moisture measurement inside the clothing.

Misc.

* This machine will not be available in the U.S. market until late 1995. According to a company representative, Miele test units will arrive in the summer of 1995, and product launch will be later in the year. Brochures about the new system will be available this summer.

American Dryer System ADS30,ADS50,ADS75

* Order from: American Dryer Corp.
  88 Currant Rd.
  Fall River, MA 02720-4781
  (508) 678-9000

* 30, 50, and 75 lb. models are available (with steam heating).

* Steam and electric heat are offered. Gas is not recommended for wet cleaning.

* Drying cycles: For light loads, 5- 15 minutes. For average loads 10-15 minutes.

* Has programmable drying times and temperatures.

* This dryer unit has the same type of internal moisture sensor as the Unimac dryer. It uses a temperature sensor to estimate the moisture content and calculate the proper drying time.

* Has anti-wrinkle feature

* Digital controls display temperature and % dryness, as well as the time remaining.

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