United States
Environmental Protection
Agency

Office of Pollution Prevention
and Toxics
Washington, DC 20460

EPA/774/R-92/002
November 1992

EPA

Proceedings

International Roundtable on Pollution Prevention and Control in the Drycleaning Industry

May 27-28, 1992
Falls Church, VA

Proceedings of an

EPA Design for the Environment International Roundtable

Pollution Prevention and Control in the Drycleaning Industry

May 27-28, 1992

Marriott Fairview Park

Falls Church, VA

Economics, Exposure, and Technology Division

Office of Pollution Prevention and Toxics

U.S. Environmental Protection Agency

Washington, DC

Prepared by Eastern Research Group, Inc. for the Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency. Points of view expressed in this proceedings document do not necessarily reflect the view or policies of the U.S. Environmental Protection Agency or any of the contributors to this publication. Mention of trade names and commercial products does not constitute endorsement of their use.

Conference Planning Committee

Jean E. (Libby) Parker and Ohad Jehassi
Regulatory Impacts Branch
Economics, Exposure, and Technology Division (TS-779)
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street, SW.
Washington, DC 20460
(202) 260-0676

Jeff Cantin and Kate Schalk
Eastern Research Group, Inc.
110 Hartwell Avenue
Lexington, MA 02173-3198
(617) 674-7200

Editor: John Bergin
Typesetting: Carl Bonvini
Cover Art: David Cheda

Copies of this proceedings document may be ordered from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Contents

Ground-Water Contamination

Capital Formation

Regulatory Activities in the United States

Information Dissemination

Foreword

The *International Roundtable on Pollution Prevention and Control in the Drycleaning Industry* was held on May 27-28, 1992, in Falls Church, Virginia. The roundtable was sponsored by the U.S. Environmental Protection Agency and was attended by representatives of industry trade associations, various U.S. and international government agencies, state agencies, and numerous research and academic institutions. Approximately 70 individuals took part.

The roundtable focused on identifying exposures to perchloroethylene, the primary chemical solvent used in the drycleaning process, and on ways to reduce or minimize such exposures.* The idea for the roundtable grew out of the Design for the Environment (DfE) Program, run by the EPA Office of Pollution Prevention and Toxics (OPPT), the sponsors of the roundtable. DfE refers to efforts made by EPA to assist industry in designing products and processes (including chemicals) so as to minimize their adverse human and environmental impacts throughout the product lifecycle and across all environmental media (air, water, solid waste). Thus, roundtable participants addressed exposures due to releases in the drycleaning shop; to the ambient air and to water; and that affect workers, residents of nearby apartments and businesses, consumers of drycleaning services, and users of threatened ground-water supplies.

OPPT's objective for the roundtable was to assemble the most knowledgeable experts on pollution issues in the drycleaning industry, to compare notes with them, and to attempt to identify options for reducing chemical exposures. To that end, OPPT invited participants to submit whatever technical information they had available so that it could be considered in future EPA activities involving the drycleaning industry. Additional materials or information are welcome and should be forwarded to: Ohad Jehassi, Economics, Exposure, and Technology Division (TS-779), Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460.

*Throughout these proceedings, authors refer to the chemical *perchloroethylene* (CAS No. 127-18-4) by several alternate names or acronyms, including *perc, PCE, tetrachloroethylene,* and *tetrachloroethene.* The terms are chemically equivalent and are used interchangeably.

These proceedings contain transcribed presentations and copies of the papers presented during the roundtable. The roundtable format was adopted to encourage discussion and to maximize interaction between participants. The program was divided into ten panels spread over the two-day period. Each panel featured 3 to 5 speakers and an open discussion session lasting 45 to 60 minutes. The proceedings reflect this format. The papers or transcribed presentations for each panel appear together, followed by a written summary of the discussion session.

A list of participants and their affiliations is included in Appendix A. Supplemental materials provided by participants following the roundtable are included in Appendix B.

Opening Remarks

Mary Ellen Weber, Ph.D.
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency

As director of the Economics, Exposure, and Technology Division in the EPA's Office of Pollution Prevention and Toxics, Dr. Weber is responsible for all engineering, exposure, industrial chemistry, and economic analyses carried out by the EPA on toxic substances. Before joining the EPA, she taught economics at Smith College and held a position as an economist at the World Bank. She holds a doctorate in economics from the University of Utah.

One of the most promising new activities at EPA is the Design for the Environment (DfE) Program. It embodies the concept of designing environmental considerations into products, processes, and even the basic building blocks—chemicals—so that the creation of pollution can be prevented instead of requiring treatment. The program has a number of components including the Small Business Initiative, under whose aegis this *International Roundtable on Pollution Prevention and Control in the Drycleaning Industry* is being sponsored. Knowing about the overall program provides a broader context for EPA's efforts to help the drycleaning industry.

EPA believes that pollution prevention opportunities should be explored throughout the lifecycle of a product and therefore our DfE Program begins with the design of the basic chemical. EPA has solicited proposals on alternative approaches to synthetic chemical pathway design from all the Ph.D.-granting chemistry departments in the United States and expects to award six research grants. EPA hopes that this project will not only yield more environmentally benign chemicals but raise awareness of environmental considerations at the molecular level in designing chemicals and microorganisms.

Subsequent steps in the program's chronology address the selection of chemicals, processes, and products and their ultimate packaging, use, and disposal. EPA had established a center at the University of Michigan to foster the incorporation of pollution prevention goals and a design-for-environment mentality in the curricula of graduate and undergraduate courses in chemical engineering, business, and natural resources. It is our goal that as each new generation of graduates enters the workplace it will bring along a design-for-environment approach to performing jobs. A number of other universities are working with the center at the University of Michigan to incorporate the DfE tenets into their activities.

Another component of the Design for the Environment Program is under development. That is a program for the large, well-financed, and technologically sophisticated members of the U.S. economy in which major value-added input will include information on relative risk of alternative chemicals and technologies and a protocol for conducting internal DfE inventories to search for pollution prevention opportunities.

A DfE Program component that EPA is particularly excited about, however, is the Small Business Initiative, which includes the Drycleaning Roundtable. There are several common elements to all EPA small business initiatives. First, the DfE small business initiatives include a commitment to apprise the industry of EPA's current and planned actions affecting the industry. EPA believes that functioning as an informal clearinghouse for regulatory and nonregulatory activity related to a particular industry is a valuable service that can be provided to the drycleaning and the other industries with whom the EPA is working closely on DfE activities.

Second, the EPA Office of Pollution Prevention and Toxics can provide industry with comparative risk information on potential substitutes. In addition, it can help develop protocols for businesses to independently conduct their own design-for-environment opportunity audits.

Third, the DfE Program can act as a facilitator in the creation and sharing of information through workshops, roundtables, and conferences.

Shortly the Design for the Environment Program will be hosting the first in a series of meetings to address DfE opportunities in the printing industry. EPA is further along in this industry than in drycleaning because it has already identified numerous potential substitute chemicals and processes, and now the printing group will be working on ways to test and evaluate the most promising alternatives. Another key element of that project will be the dissemination of information to the many small printers in the industry. EPA expects to do this by creating a manual and videotapes of alternative chemicals and technologies in action, and by holding a televideo conference that has the potential of economically reaching printers throughout the country.

This drycleaning roundtable is an exploratory first step and it arises out of a long-standing interest at EPA and in the drycleaning industry in potential occupational, consumer, and environmental exposure to perchloroethylene (perc), and the search for alternative chemicals, practices, and technologies.

Simply exchanging information could create some exciting new ways to look at reducing exposure to perc. For example, sharing engineering and economic feasibility analyses is useful in jointly pursuing pollution prevention opportunities.

EPA has been looking at perc since 1986 when it began the interagency investigation of methylene chloride—and several of its substitutes, including perc—and identified the drycleaning industry as a major user. Since then, industry and interagency work groups have each investigated various aspects of perc exposure. Drycleaning industry associations have been attempting to publicize environmentally sound chemical management and disposal practices among members.

The purpose of this roundtable is to encourage cooperation between the members of the drycleaning industry and government. This roundtable offers both EPA and the industry an opportunity to look at old information in new ways, to think in new ways, and to act in new ways. Your willingness to gather together here today to begin to look at ways to cooperatively examine the various issues surrounding the use of perchloroethylene in the drycleaning industry is appreciated. Thank you for joining us in this endeavor.

EXPOSURE REDUCTION

Overview of Exposure Pathways

Jeff Cantin
Eastern Research Group, Inc.

Mr. Cantin is a senior economist with Eastern Research Group, an environmental and economic consulting firm in Lexington, Massachusetts. ERG specializes in assisting federal regulatory agencies such as the Environmental Protection Agency, the Occupational Safety and Health Administration, and the Department of Transportation in evaluating the economic impacts of their regulatory proposals.

This presentation profiles the U.S. drycleaning industry, examines the industry's current level of pollution prevention, identifies human chemical exposure pathways, and estimates the potential magnitude of such exposures.

Demographics of the Drycleaning Industry

In the United States, the drycleaning industry is composed of three different sectors. These are:

Commercial sector—consists primarily of neighborhood-based shops that accept garments such as suits, blouses, and dresses directly from the consumer for cleaning and treating. Many of these are family owned and operated, with a significant percentage, perhaps 25 percent nationally, operated by owners of Korean descent. Most shops have one or more drycleaning machines onsite, although sites that serve as drop-off locations only are also common. Machines at these shops are typically in the 30 to 60 lb (13.5 to 27 kg) capacity range, with facilities typically processing 75,000 to 100,000 lb (33,750 to 45,000 kg) of clothing each year.

Industrial sector—consists of large facilities operating multiple high-capacity machines and processing high volumes of cleaning. Much of the industrial sector concentrates on cleaning uniforms, rugs and mats, rags, and linens, which are supplied on a rental basis to business, industrial, or institutional customers.

Coin-op sector—consists of small capacity (8 to 12 lb, or 3.6 to 5.4 kg) coin-operated machines (coin-op), usually found in conjunction with coin-op laundromat facilities. These machines allow the consumers to have clothing drycleaned while they wait. In some cases the consumer operates the machine directly, while in others an attendant is charged with machine loading and unloading.

Solvent Usage

An estimated 82 percent of all commercial drycleaning shops use perchloroethylene (perc) as their primary cleaning solvent. The remainder use petroleum solvents (15 percent), CFC-113 (3 percent), and 1,1,1 trichloroethane (less than 1 percent) (EPA, 1991b). In the industrial sector, perc use has become less and less common as new detergent-based formulations have been adopted. Virtually all coin-op machines use perc.

Definitive data on perc consumption in drycleaning is not readily available. So-called bottom-up calculations use information on the number and type of machines in use, their capacity and throughput (pounds of clothes cleaned annually), and estimates of perc consumption per unit of throughput.[1] Calculated in this manner, perc consumption in 1987 has been estimated at 131,796 metric tons (SRRP 1990). In the alternative, using a top-down approach the share of total domestic perc consumption used in drycleaning is estimated at 132,000 tons. Thus, the two approaches yield similar results. Recent calculations for 1991 estimate fresh perc consumption in drycleaning at 124,000 tons (EPA, 1991b).

In addition to fresh solvent, the drycleaning industry consumes an estimated 6,100 tons of recycled perchloroethylene (EPA, 1991b). This quantity has

[1] Perc consumption is estimated at 12 lb (5.4 kg) per 100 lb (45 kg) of clothes cleaned in the commercial, industrial, and coin-op sectors (SRRP, 1990).

been estimated by Safety Kleen, a major provider of hazardous waste services to the drycleaning industry. Table 1 shows the consumption of fresh and recycled perc for the commercial, industrial, and coin-op sectors in 1991.

Table 1. Consumption of perchloroethylene in the drycleaning industry, 1991 (metric tons).

Sector	Consumption Fresh	Consumption Recycled	Total Consumption
Commercial	116,900	5,800	122,700
Industrial	5,700	300	6,000
Coin-Op	1,400	—	1,400
TOTAL	124,000	6,100	130,100

Source: EPA, 1991b.

Machine Populations

Estimates of drycleaning machine populations in the three sectors were recently developed as part of the EPA's efforts under the 1990 Clean Air Act Amendments to regulate the air emissions of perc from drycleaning facilities. Table 2 indicates that in 1991 there were approximately 31,000 perc machines operated by the commercial sector, 130 perc machines operated by the industrial sector, and 3,000 perc machines used in the coin-op sector.

Table 2. Drycleaning machine populations, 1987-1991.

Year	Commercial	Industrial	Coin-Op	TOTAL
1987	31,575	162	4,013	35,750
1989	31,433	145	3,493	35,071
1991	31,434	130	3,044	34,608

Source: Radian, 1991a.

Growth in the commercial drycleaning sector is currently flat or declining, with a slight decrease in machine populations detected between 1987 and 1991. In the industrial sector, the number of perc machines is declining as they are replaced with water-based laundering machines (Radian, 1991a). Following a period of rising popularity in the 1960s, coin-op machines are being phased-out due to economic and environmental factors (French and McNeilly, 1988).

Drycleaning machines are classified according to whether the washing and drying units are separate (i.e., transfer machines) or if both functions are performed in one unit (i.e., dry-to-dry machines). With the older transfer technology, the garments must be physically transferred to the dryer following the washing and extraction cycles. In the newer, dry-to-dry machines, the garments are washed and dried in a single unit, thereby cutting down on vapor releases to the workspace.

In the commercial sector, transfer equipment currently accounts for approximately one-third of the equipment stock. All new equipment being sold in this sector is of the dry-to-dry design, although some used transfer equipment may still be available (Radian, 1991a). In the industrial sector, some 84 of 130 perc machines (or 65 percent) are transfer-type units. All coin-op machines are the dry-to-dry type.

Emissions from the Drycleaning Process

The 130,100 tons of fresh and recycled perc consumed annually either evaporate as process or fugitive emissions, or are lost through disposal of industry solid wastes. Using a solid waste generation factor of 2.5 kg perc per 100 kg clothes cleaned, the amount of perc disposed offsite can be subtracted from total consumption to estimate total annual emissions. Table 3 indicates that of the 130,100 tons of perc consumed annually, approximately 87,000, or 67 percent, is lost through emissions. This quantity is released to the indoor air at drycleaning shops, vented to the outdoors, or is emitted from freshly cleaned clothes into the homes of consumers. Offsite disposal of perc in solid waste is estimated at 43,100 metric tons.

Table 3. Emissions of perchloroethylene by the U.S. drycleaning industry, 1991 (metric tons).

Sector	Total Consumption	Offsite Disposal	Emissions
Commercial	122,700	40,900	81,800
Industrial	6,000	1,700	4,300
Coin-Op	1,400	500	900
TOTAL	130,100	43,100	87,000

Note: Emission estimates are derived by subtracting offsite disposal amounts from total consumption amounts.

Source: EPA, 1991b.

To reduce the amount of perc emitted, the industry must find ways to further cut fugitive emissions from the process equipment, to recover additional perc from vented emissions, or to remove residual perc from clothing prior to releasing the garments to the customer.

Emissions Sources

Solvent losses in the drycleaning process may occur through atmospheric releases, from the generated wastes, or from the discharge of contact water to the sewer system:

- Atmospheric releases may be either process-related (due to the venting of emissions) or fugitive (due to equipment leaks, losses from clothes during transfer operations, or losses during solvent transfer).

- Generated wastes include still bottoms, filter "muck," and spent filter cartridges. These wastes are normally considered hazardous and are typically removed from the facility by a hazardous waste processor for offsite recovery and disposal.

- A small amount of perc is contained in water removed from the perc-water separator. Traditionally, this water has been discharged to the sewer system.

Emissions Controls

Two main technologies are available for controlling drycleaning machine emissions: *refrigerated condensers* and *carbon adsorbers*. Refrigerated condensation units cool the perc-containing vapors to recover solvent, while carbon absorbers remove perc molecules by passing the vapors over a bed of activated carbon. The carbon bed is then desorbed using steam, and the perc is recovered from the desorption liquid. Both carbon adsorbers and refrigerated condensers are available as original equipment or as add-on controls.

The effectiveness of these technologies in reducing fugitive and process emissions is shown in Table 4. In general, refrigerated condensers will reduce process emissions by 95 percent on dry-to-dry machines and by 85 percent on transfer machines. Carbon adsorbers are somewhat more effective in controlling process emissions from transfer machines, and will reduce these emissions by 95 percent as well.

An additional control method used by a small percentage of the industry is the Solvation™ process. In this system, the perc-laden vapors are passed through a water bath, where they form an azeotropic mixture of water and perc.[2] The vapor pressure of this mixture is lower than that of perc, which increases the recovery efficiency of the machine's normal condenser. The effectiveness of this technology is believed to be approximately equal to that of refrigerated condensers, but was not deemed sufficient for compliance with EPA's National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA, 1991b).

Table 5 indicates the level of adoption of the two primary means of control in the commercial, industrial, and coin-op sectors as of 1990. (Use of the Solvation™ process is believed to be currently limited to less than 5 percent of the industry.) The major highlights from the table follow:

- Approximately half of all transfer machines in the commercial sector are uncontrolled. Among controlled machines, half are equipped with refrigerated condensers and half with carbon adsorbers.

- Some 32 percent of commercial dry-to-dry machines are currently uncontrolled. Forty-seven percent are equipped with refrigerated condensers, and the remaining 21 percent are fitted with carbon adsorbers.

- In the industrial sector, 50 percent of all transfer and dry-to-dry machines are estimated to

Table 4. Emissions factors for drycleaning machines (kg perc per 100 kg clothes cleaned).

Type of Control	Dry-to-Dry Machines: Emissions (kg)	Dry-to-Dry Machines: Control Effectiveness	Transfer Machines: Emissions (kg)	Transfer Machines: Control Effectiveness
Uncontrolled				
Process emissions	3.1		4.0	
Fugitive emissions	2.5		5.0	
Total emissions	5.6		9.0	
Refrigerated condenser				
Process emissions	0.2	93.6%	0.6	85.0%
Fugitive emissions	2.5	0.0%	5.0	0.0%
Total emissions	2.7	51.7%	5.6	37.8%
Carbon adsorber				
Process emissions	0.2	93.6%	0.2	95.0%
Fugitive emissions	2.5	0.0%	5.0	0.0%
Total emissions	2.7	51.7%	5.2	42.4%

Source: EPA, 1991b.

Table 5. Drycleaning machine populations and current levels of pollution control, 1991.

Type of Machine and Level of Control	Sector: Commercial	Sector: Industrial	Sector: Coin-Op	TOTAL
Transfer machines				
Uncontrolled	5,253	42	—	5,295
Refrigerated condenser	2,529	—	—	2,529
Carbon adsorber	2,529	42	—	2,571
Total	10,311	84	—	10,395
Dry-to-dry machines				
Uncontrolled	6,885	23	1,617	8,525
Refrigerated condenser	9,978	—	—	9,978
Carbon adsorber	4,532	23	1,427	5,982
Total	21,395	46	3,044	24,485
TOTAL	31,706	130	3,044	34,880

Source: Radian, 1991a.

[2] An azeotrope is defined as a liquid mixture that is characterized by a constant minimum or maximum boiling point that is lower or higher than that of any of the components and that distills without change in composition.

be uncontrolled, while the other 50 percent are equipped with carbon adsorbers.

- As noted above, all coin-op machines are of the dry-to-dry design. About half (53 percent) are uncontrolled, while the remainder (47 percent) are equipped with carbon adsorbers.
- Vented machines are equipped with fans that pull air into the machine and away from the operator when the door is opened. Newer, no-vent machines eliminate the induction of fresh airflow into the machine and therefore eliminate these emissions. Approximately half of dry-to-dry machines in the commercial sector are vented, while the other half are of the no-vent design.

Overall, 13,820 of 34,880 machines are uncontrolled (40 percent), 12,507 are equipped with refrigerated condensers (36 percent), and 8,553 feature carbon adsorbers (25 percent).

Solid Wastes

Solid wastes in the drycleaning industry are generated by the filtration and distillation processes integral to the modern drycleaning machine.

Filtration—Drycleaning machines recirculate used solvent and employ continuous filtration systems to ensure the purity of the solvent supply to the washer. The filters remove insoluble soil and other contaminants from the perc during the cleaning cycle. Cartridge-type filters are the most common, and are now used by an estimated 90 percent of the commercial industry (Wentz and Stucker, 1990). The cartridges must be changed following cleaning of between 450 and 700 lb (202.5 and 315 kg) of clothing. Cartridges are normally removed, drained overnight, and then discarded. The spent cartridges, however, can retain as much as one gallon of perc. Steam stripping may be used to remove additional solvent prior to disposal.

A smaller number of drycleaners employ regenerative filters, which are either rinsed and reused or which employ a rechargeable filter medium, such as clay or diatomaceous earth. The filter medium is removed and replaced with fresh medium. The spent filter medium in rechargeable filters can also retain significant quantities of solvent.

Distillation—Distillation is a companion process to filtration and serves to purify and recover the used solvent. Recovery is performed for both economic and environmental reasons, and distillation is practiced by close to 90 percent of commercial drycleaners (IFI, 1989). Distillation units are built into most modern drycleaning machines.

In the distillation process, used solvent is heated in a still to its boiling point (250°F, or 121°C). The perc and any water vaporize, leaving behind the nonvolatile residues such as detergents, waxes, dyestuffs, sizing, oils, and grease. The distilled perc/water mixture is then left to stand in a gravity separator unit, where the heavier perc separates from the water and is drained from the bottom of the separator to the solvent tank. The water, containing small quantities of perc, is decanted from the top of the separator.

The sludge (or still "bottoms") that accumulates in the bottom of the still is removed for disposal. Still bottoms may contain as much as 50 percent perchloroethylene (SRRP, 1990). To remove additional perc prior to disposal, approximately 20 percent of the industry utilizes "muck" cookers (IFI, 1989).

Under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA), still bottoms and cartridge materials are considered hazardous wastes. Regulations promulgated in 1986 under RCRA prohibit the land disposal of wastes containing more than 1 percent (10 ppm) of chlorinated solvent (RCRA, 1986). All drycleaner wastes must be removed for disposal at an appropriate facility (e.g., incineration) or be further recycled. According to industry sources, some 80 percent of waste solvent and residue is picked up and recycled offsite (Meijer, 1988, cited in SRRP, 1990).

Chemical Exposure Pathways

Releases of perc from the drycleaning process have the potential to impact various environmental media including indoor air, ambient air, land, surface water and ground water. This section describes potential human exposure pathways for these releases and provides estimates of the potential number of exposures of each type.

Indoor air—Perc vapors released or emitted to indoor air can affect drycleaning workers; residents of apartments in the vicinity of drycleaners; patrons and employees of restaurants, food stores, and other commercial establishments located nearby; and consumers that bring drycleaned garments into the home.

Ambient air—Ambient air releases can impact general air quality and may also be drawn into apartments or other nearby establishments through open windows, vents, or air conditioning systems.

Solid waste—Disposal of perc as solid waste can affect ground or surface water as these materials leach from landfills.

Surface and ground water—Disposal of perc through sewers can affect the quality of receiving surface waters. When sewer pipes leak, ground-water and drinking-water supplies may be endangered.

Worker Exposures

The U.S. Occupational Safety and Health Administration (OSHA) estimates that there are some 19,369 drycleaning establishments with payroll in the United States.[3] Of these, 85 percent or an estimated 16,464 use perc. Employment at these facilities is estimated at 157,950 workers.

OSHA's 1989 Permissible Exposure Limit (PEL) for workers was set at 25 ppm over an 8 hour day. Until December 1993, facilities can require employees to us personal protective equipment to meet these exposure limits. After this date, however, engineering controls must be in place. The 25 ppm limit has been challenged by both labor groups and the drycleaning industry, and the entire PEL standard for air contaminants was recently remanded by the courts.

Apartment Resident and Business Exposures

Residents of apartments located above or adjacent to drycleaning establishments may be exposed to perc emissions that enter their apartment. Likewise, employees of businesses situated near drycleaners may also experience exposure to perc emissions. The mechanisms by which perc can enter apartments or nearby businesses include:

Diffusion—Perc can pass through floor, ceiling, and wall materials from the drycleaning shop into adjacent apartments or businesses.

Indoor airflow—Perc can be carried through holes in ceilings, pipe chases, vents, and other airflow paths within an apartment or multi-establishment building.

From the outdoors—Perc emissions vented from the shop to the outdoors can be drawn into apartments or other businesses through open windows or ventilation units.

Studies in New York City and elsewhere in New York State have found perc concentration levels averaging 0.04 to 8.1 ppm in apartments located above or adjacent to drycleaning shops, with a maximum reading in one apartment of 28.6 ppm.[4] Although these levels are generally below the OSHA worker standard of 25 ppm, it should be noted that some apartment residents (e.g., invalids, pregnant women) may have longer exposure periods than workers and others (e.g., infants) may be more sensitive to exposure than the average drycleaning worker.

Of the 29,718 drycleaning establishments in the United States, those located in urban areas (and especially older cities) are more likely to be located in apartment buildings. Nationally, there are no estimates of the number of facilities in apartments. Surveys of drycleaners in New York City suggest that 397 of 1,181 drycleaners (or 34 percent) are located within apartment buildings (Schreiber, 1992). Elsewhere in New York State, however, the percentage of cleaners in apartment buildings is much lower—only 6 percent. Officials from California have indicated that relatively few drycleaners are in apartment buildings even in greater Los Angeles. In Michigan, drycleaners have been prohibited from operating in apartment buildings (and food stores) for several years, hence resident exposures are believed to be minimal.

In both urban and rural areas, drycleaners are also found in buildings that house other businesses. These include structures such as high-rise office buildings and, more commonly, strip malls. In New York City, approximately 43 percent of drycleaners surveyed indicated they share a building with one or more other businesses. Elsewhere in the State of New York (i.e., excluding New York City), 47 percent of drycleaners are located adjacent to other businesses (Schreiber, 1992).

ERG has developed estimates of the number of apartment residents potentially exposed to drycleaning emissions. Nationally, 75 percent of the U.S. population live in urbanized areas[5] (Miller, 1992). Consumer expenditure surveys indicate that urban consumers spend twice as much on drycleaning as rural consumers (Rogers, 1992). We assume that the number of drycleaners in urban and rural areas is proportional to the urban-rural population distribution, adjusted for the intensity of use of drycleaning services. If the urban-rural split of population is 3:1, and urban consumers use drycleaning twice as much, then the 29,718 drycleaning establishments can be allocated using an urban-rural ratio of 6:1. Thus, 25,473 drycleaners are estimated to be located in urban areas and 4,245 are located in rural areas.

Using Census Bureau data on the number of apartment units in the United States and the estimates derived above, the number of apartment residents potentially exposed to drycleaning emissions can be estimated. If 20 percent of cleaners in urban areas and 5 percent of rural cleaners were assumed to be located in apartment buildings, then 857,000

[3]An additional 5,794 establishments are estimated to operate without payroll, that is, without paid employees. These are primarily smaller, family operated facilities. Non-payroll establishments are not covered under the 1970 Occupational Safety and Health Act, and hence are not included in the OSHA estimate.

[4]The New York studies are described in more detail in the two papers by Schreiber found elsewhere in these proceedings.

[5]Defined by the Census Bureau as "one or more places ('central place') and the adjacent surrounding territory that ('urban fringe') together have a minimum of 5,000 persons."

urban and 35,000 rural apartment residents could be exposed to drycleaning emissions.[6]

Consumer Exposures

Consumers may be exposed to any residual perc that remains in their garments following dry cleaning. When drycleaning equipment is operated properly, the amount of perc remaining in clothing should be minimal. If the drycleaning equipment is not functioning well, however, or if the cleaner has not allowed sufficient drying time, some garments may contain substantial residual amounts of perc.

Freshly cleaned garments are normally brought back into the home and hung in closets, which may be located in the bedroom of the consumer. Studies by EPA and industry have found that garments will "offgas," or release, perc into the home over a period of time. In an EPA indoor air test house, maximum readings in various parts of the house ranged from 2,900 ppb in the closet to 195 ppb in the bedroom and 83 ppb in an adjacent den (as shown in Table 6).[7]

Drycleaning is one of the most common types of "personal services" used by consumers in the United States. Each year, U.S. consumers send approximately 600,000 metric tons of clothing and other items to their drycleaner (EPA, 1991a). Consumer expenditure surveys indicate that the average household spends approximately $66 per year cleaning 11 kg (22 lb) of clothing (Rogers, 1992). Surveys by EPA in 1987 found that 51 percent of respondents indicated they had used drycleaning services within the previous 12 months (EPA, 1987). Among users of drycleaning services, the mean number of times drycleaning was used per month was 1.87. Based on these figures, EPA estimates that approximately 100 million consumers are exposed to perc residuals in clothing every year.

Table 6. Maximum concentrations of perchloroethylene in EPA experimental test house.

Location	Maximum Concentration (ppb)	Control Concentration (ppb)
Closet	2,900	no detect
Bedroom	195	no detect
Den	83	no detect

Source: EPA, 1988.

[6]The Census data indicates the number of apartment *units* by size of *structure*, using the following size classes: 2-4, 5-9, 10-19, 20-49, and <50. To estimate the number of structures in each size class, the number of units was divided by the midpoint of each size class. for the >50 size class, an average size of 125 units was used. The number of drycleaners estimated to be located in apartment structures (20 percent of urban cleaners and 5 percent of rural cleaners) were then allocated among the size classes as follows: 5 percent in buildings with 2-4 units; 5 percent in buildings with 5-9 units; 20 percent in buildings with 10-19 units; 30 percent in buildings with 20-49 units; and 40 percent in buildings with >50 units. The number of structures with drycleaners in each size class was then multiplied by the average number of units, which in turn was multiplied by the mean household size in urban and rural areas.

[7]The paper by Tichenor in these proceedings discusses the findings of the EPA study in more detail.

Food Exposures

Because perchloroethylene is somewhat lipophilic (i.e., absorbed by fatty cells and tissues), it has been found in various food products by several researchers. The potential for absorption of perc vapors by food is highest in food stores, restaurants, and apartment residences located adjacent to, above, or near drycleaning establishments.[8] The amount of perc absorbed by food depends on numerous factors such as the concentration of vapors, the amount and type of packaging, and the length of storage and exposure to perc emissions.

Ground-Water Exposures

Ground-water contamination problems may arise if there are frequent or large spills of perchloroethylene during the transfer of solvent from delivery trucks to the drycleaning machine. An additional source of potential contamination, and one that has received most attention of late, is the disposal of separator water into the sanitary sewer system.

Although drycleaning is a non-aqueous process, water is still involved. Following the cleaning cycle, for example, used perc will contain a certain amount of water that has been released from the garments (e.g., perspiration). Some drycleaning machines purposefully introduce a small amount of water and detergent into the washer to assist in removal of water-borne contaminants. Condensed perc vapors from the reclaimer unit also contain water.

Before this perc can be reused, the water must be removed. Used perc and condensed vapors are usually pumped to a separator tank, where gravity serves to separate the heavier perc from the lower density water. The perc is drained from the bottom of the tank and the water is decanted off the top (Radian, 1991).

Traditionally, the water coming off the top of the separator is disposed of via the sanitary sewer system. Operators either poured the water down the drain or attached a hose to the machine and placed the hose in the drain. The quantity of water generated depends upon the type of vapor recovery unit in place. Machines with refrigerated condensors can generate approximately 250 gallons (950 liters) per year of water (1 gallon, or 3.8 liters, per day), while those equipped with carbon adsorption units can generate double that amount, due to the higher volume of vapors that are processed.

The solubility of perchloroethylene in water is approximately 150 ppm. If the perc-water mixture is at equilibrium, then the amount of perc contained in separator water will range from 0.03 kg to 0.85 kg (0.066 to 1.87 lb) annually, depending on the control

[8]See the presentation by Diachenko in these proceedings.

device in place (Radian, 1991b). If the water is removed before the perc has fully separated, however, the water could contain substantially greater amounts of perc (CVRWQCB, 1992).

Although the amounts of perc disposed to sewers in separator water may appear small, investigations in California have recently linked the disposal of this water to sewers as a major source of ground-water contamination.[9] There, several mechanisms have been identified to explain the leakage of perc out of sewers and into aquifers below. Legal actions against several drycleaners, drycleaning equipment operators, and cities that constructed and operate the sewer system are under way.

Test wells drilled near drycleaning facilities in Modesto, California, have found perc concentrations averaging 3,470 ppb with a maximum of 32,000 ppb. Levels measured in actual municipal wells in Turlock, California, ranged from <0.5 ppb to 7.2 ppb (Cohen, 1992). Under the Safe Drinking Water Act, the maximum contaminant level (MCL) for perchloroethylene is 5 ppb, and the maximum contaminant goal (MCG) is 0 ppb.

The extent of ground-water contamination or the magnitude of the threat due to past disposal of separator water by drycleaners is unknown. In addition to the investigations occurring in California, similar problems are under study in Florida (Morgan, 1991) and Maryland (Haddad, 1991).

In the United States, approximately 123 million people obtain their drinking water from ground-water sources (EPA, 1988).

References

Cohen, W., 1992. Personal communication between Wendy Cohen of the Central Valley Regional Water Quality Control Board and Jeff Cantin of ERG. May.

CVRWQCB, 1992. *Dry Cleaners—A Major Source of PCE in Ground Water*. March 27. State of California Regional Water Quality Control Board. Central Valley Region.

EPA, 1987. U.S. Environmental Protection Agency. *Household Solvent Products: A National Usage Survey*. EPA-OTS 560/5-87-005. July.

EPA, 1988. U.S. Environmental Protection Agency. *Environmental Progress and Challenges: An Update*. EPA-230/07-88-033.

EPA, 1991a. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Standards Division. *Economic Impact Analysis of Regulatory Controls in the Dry Cleaning Industry*. EPA-450/3-91-021. October.

EPA, 1991b. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Standards Division. *Dry Cleaning Facilities—Background Information for Proposed Standards*. EPA-450/3-91-020A. November. 56 Fed. Reg. 236 at 64, 382 (Dec. 9, 1991).

French, M.T., and L.D. McNeilly, 1988. *Economic Impact Analysis of Regulatory Controls in the Dry Cleaning Industry*. Prepared for the U.S. Environmental Protection Agency, OAQPS, Economic Analysis Branch by the Center for Economics Research, Draft Report, March.

Haddad, 1991. "State seeks to recoup cost of ground-water cleanup; officials negotiate over contamination from dry-cleaner business," *Baltimore Sun*. Sunday, February 17, 1991.

IFI, 1989. International Fabricare Institute. *Equipment and Plant Operations Survey, Focus on Drycleaning*. Vol. 13(1). March.

Meijer, J., 1988. Personal communication between J. Meijer of the International Fabricare Institute and A. Yazdani of the Source Reduction Research Partnership. February.

Miller, J., 1992. Personal communication between Joel Miller of the U.S. Bureau of the Census, Economic Geography Division, and Jeff Cantin of ERG. June.

Morgan, C., 1991. "Dry cleaners' dirty legacy—Pollution in drinking water," *Miami Herald*. By Curtis Morgan. Monday, December 2, 1991.

Radian, 1991a. *Documentation of Growth Rates for the Dry Cleaning Industry*. (Memorandum to drycleaning NESHAP file.) Radian Corporation. March 29.

Radian, 1991b. *Evaluation of Separator Water Disposal Practices*. (Memorandum to drycleaning NESHAP file.) Radian Corporation. October 8.

RCRA, 1986. Resource Conservation and Recovery Act. *Hazardous Waste Management System: Land Disposal Restriction—Final Rule*. 51 Fed. Reg. 40,572 (Nov. 7, 1986).

Rogers, J., 1992. Personal communication between John Rogers of the Division of Consumer Expenditure Surveys, Bureau of Labor Statistics, and Jeff Cantin of ERG. February.

Schreiber, J., 1992. Personal communication between Judy Schreiber of the New York State Department of Health, Bureau of Toxic Substances Assessment, and Jeff Cantin of ERG. September.

SRRP, 1990. Source Reduction Research Partnership. *Source Reduction of Chlorinated Solvents—Dry Cleaning of Fabrics*. Final Draft, June.

Wentz, M.W., and J.F. Stucker, 1990. *Removing Perc from Used Cartridges and Still Residues, American Drycleaner*, June.

[9] See the presentations by Cohen and Bunte in these proceedings, as well as the CVRWQCB report cited in the References section.

German Drycleaning Regulations and Technology

Josef Kurz, Ph.D.

Research Institute Hohenstein

Josef Kurz is director of research on textile drycleaning at the Institute Hohenstein, in Boennigheim, Germany, where he has worked as a scientist for over 35 years. The current emphasis of his work is on the ecology and application of solvents used in drycleaning. He is a lecturer at the Technical Academy Hohenstein, and in 1984 he served as a visiting professor at the University of Helsinki. His research and educational work have been documented in 15 books and approximately 200 other publications.

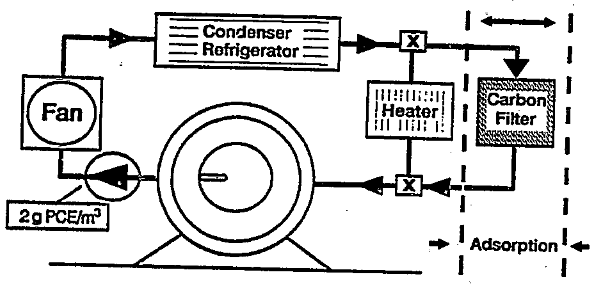
This presentation provides information on pollution prevention from the German drycleaning industry. Germany has very strict regulations on emissions into the air, the ground, the workroom, and residential areas. I would like to highlight what is important from my point of view.

Regulation of Perc Vapor Concentrations

Regulation requires that drycleaners combine and optimize condensation and absorption. That means that we have to combine the condensation cycle with the absorption cycle in a carbon filter. The requirement is that the concentration of perchloroethylene (perc, or PCE) in the air leaving the cage may not be higher than 2 g/m^3, which is about a tenth of the normal concentration from closed machines with a condenser and refrigerator (Figure 1). This system is very effective, but it needs a lot of time to reduce the concentration of perc to 2 g/m^3. Essentially, there is a device to measure the concentration. Exhausting, or open, machines, as we call them, have the same perc vapor concentration after the cage, but the air that has passed the carbon filters must not have perc loadings of more than 20 mg/m^3 or about 3 ppm (Figure 2). So that means about three ppm, a value that also has to be measured by our measuring device.

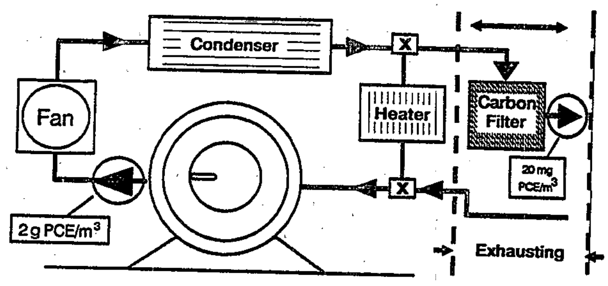
The impacts of this regulation are the following. We have to monitor the concentration in the cage and in the drying air, and the loading door is not to be opened until the value of 2 g/m^3 perc is reached. That means the operator cannot open the door if the value is higher than 2 g/m^3.

Figure 3 presents three examples of the drying or deodorization procedure. For instance, after a condensation cycle of zero to one minute, the concentration in the air after trousers have been cleaned is about 2 g/m^3. That means the loading door can be opened, since the garments are cleaned and dried according to the regulations. With silk, the concentration after the condensation phase is about 1 g/m^3, thus the door can be opened about two minutes



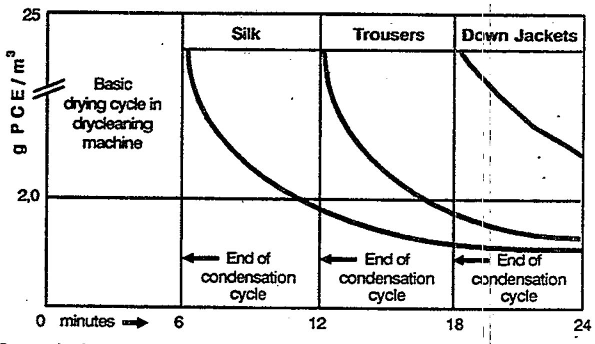
Source: Institute Hohenstein.

Figure 1. Schematic of a closed drycleaning machine with an integrated carbon filter.



Source: Institute Hohenstein.

Figure 2. Schematic of a drycleaning exhausing machine with a carbon filter.



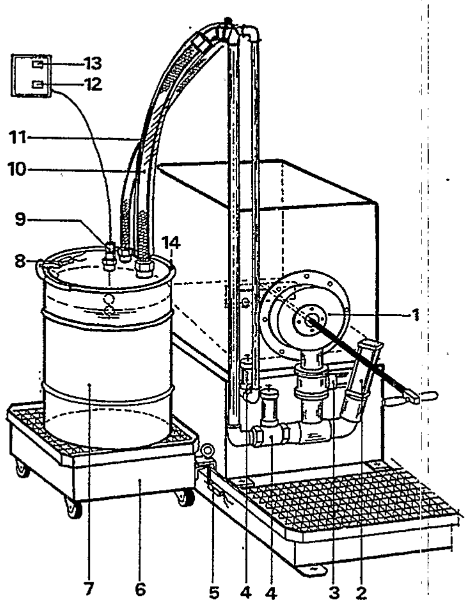
Source: Institute Hohenstein.

Figure 3. Perc concentrations in different types of garments during drycleaning cycle.

earlier. The third example uses down jackets, which present a problem for drycleaners. Here two down jackets were put in a 10 kg machine. After the drying cycle and an absorption phase of 12 minutes, the perc concentration was about 6 g/m^3. The drycleaner has to continue the absorption phase until a value of 2 g/m^3 is reached. Thus, the garments have to be cleaned another 12 minutes or more. If the machine were loaded with 8-10 kg of down jackets, drying might take two hours. So we see some difficulties with this material in the drycleaning cycle.

Removal of Still Residues and Lint

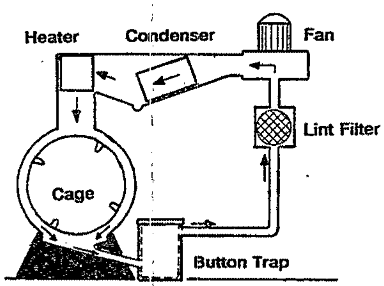
The removal of still residues must be done without releasing emissions. That means the door of the still must not be opened by hand and the residues must be removed using a waste vessel. In Germany we use a closed system, with a piston pump (Figure 4). The piston pump brings the residues into the vessel and the displaced air goes back into the still. Thus, there is an exchange of the air between the still residues and the waste vessel, and no emissions are released during the removal of the residues from the still. Since liquids, semi-liquids, and even powder or paste can be pumped, every type of residue can be removed from the still without emissions.



Source: System Multimatic.

Figure 4. Technology for removal of still residues.

It appears that the burden or load of perc released into the workroom is partly caused by vent leaks from the button traps. As a result, the German government requires that lint be removed in a dry condition. Figure 5 shows a schematic of the system used to dry this lint. The air flows from the cage to the button trap, dries the lint in the button trap, crosses the lint filter, ventilator, condenser, and heater, and then follows the normal cycle in the drycleaning machine. Emissions into the workroom are avoided and diffusion into the residential areas above the drycleaning room are likely to be minimized.



Source: Institute Hohenstein.

Figure 5. Schematic of system for removal of button trap residues.

Handling of Perc

Open handling of perc is prohibited. We have some problems with this, however, because sometimes it is necessary to handle perc in the open. It appears that 80 to 90 percent of the drycleaners in Germany are working in accordance with this regulation.

Disposal of Separator Water

Ground-water protection is very important in Germany. In the drycleaning process, contaminated water from the water separator must be purified by adsorption, stripping, or by absorption (Table 1). Normally we use absorption systems, and the threshold value for the contaminated water is 0.5 mg perc in the water going to the sewer. Before cleaning, the water generally has about 200 mg or higher per liter.

Table 1. Water protection considerations relevant to the drycleaning process.

Drain	Handling	Deposit
Purification of contaminated water of the water separator by • adsorption, • stripping, • absorption. Threshold value: 0,5 mg perc per liter water	Carefully! **Storage** Storage of solvent and solvent containing detergents /aids and distillation residues in a safety trough	• Outlet air of exhausting machines not higher than 20 mg perc / m³ (~3 ppm) • Outlet air from the workroom less than 35 mg perc / m³ (~ 5 ppm)
Regulation	Regulations	Regulations
• Law on Water Protection	• Regulation on Clean Air • Law on Water Protection	• Regulation on Clean Air • Regulation of German OSHA

Source: Institute Hohenstein.

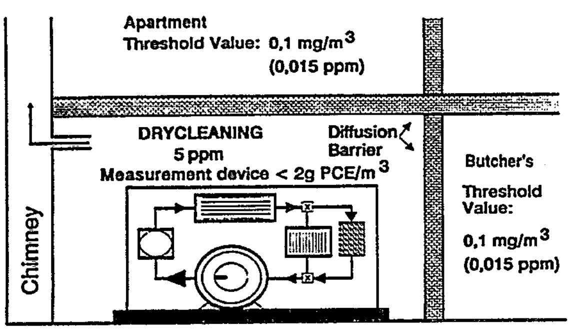
Solvent Storage

Regulations also require that solvent be handled carefully to ensure it does not get into the ground water. Storage of the solvent is an important concern. Since the penetration of solvent into the ground is prohibited, solvent and solvent-containing detergents, aids, and residues must be stored in safety drums so that leakage into the ground water is avoided.

Protection of Neighborhood Areas

Perc concentrations in gaseous exhaust from the drycleaning plant—the outlet air of the exhausting machines—must not exceed 20 mg/m^3, and the outlet air of the workroom cannot exceed 35 mg/m^3 perc, about 5 ppm. (Normally we have an occupational exposure limit value of 50 ppm.)

Figure 6 shows a diffusion barrier used to protect neighboring areas. The threshold value is 0.1 mg/m^3 perc, or 0.015 ppm, for a neighboring apartment. The diffusion barrier is very useful for reducing diffusion of emissions through walls and ceilings from the workroom of the drycleaning plant.

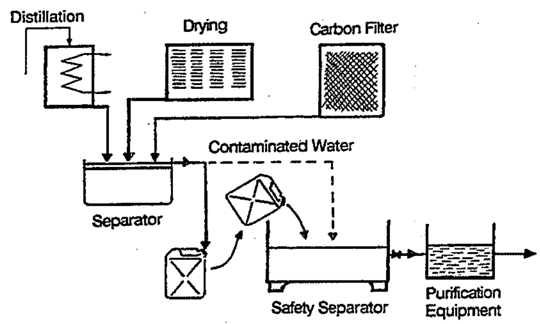


Soure: Institute Hohenstein.

Figure 6. Diffusion barrier for confining drycleaning vapors.

Collection and Treatment of Contaminated Water

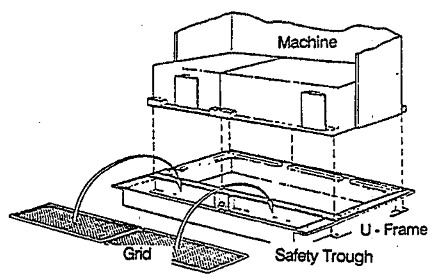
The collection of contaminated water must be carried out properly. This concerns contaminated water from distillation, plus the water from the drying cycle in the machine and from the carbon filter. All this water has to be collected in a separator—a conventional separator like in other machines (Figure 7). Then the water is directed to a safety separator—a bigger tank or vessel. Finally, the water must be purified or treated to reach a perc value of 0.5 mg/m^3.



Source: Institute Hohenstein.

Figure 7. Schematic of system of handling water contaminated by drycleaning process.

Figure 8 shows an example of a safety trough for storage of barrels. The size of the safety trough must be sufficient to hold the contents of the largest container. Also, the drycleaning machine must be set over a safety trough so that solvent can be collected if there is any leakage from the machine.



Source: Institute Hohenstein.

Figure 8. Collecting trough for containing solvent leakage.

Inspection and Training

The drycleaner must inspect drycleaning machines on a daily or weekly basis for leaks (Table 2). A simple method to control leakages must be employed, and the activated carbon filter must be inspected regularly to ensure that the value of 20 mg is not exceeded.

Designated plant personnel must be trained and tested in environmental protection practices at certified schools (Table 3). Annual training is required for

Table 2. Recommended frequency of inspection of drycleaning equipment.

Daily	Weekly
• Leaks in Drycleaning machine • Activated Carbon Filter	Contact water treatment device

Table 3. Training and external inspection considerations for drycleaning operations.

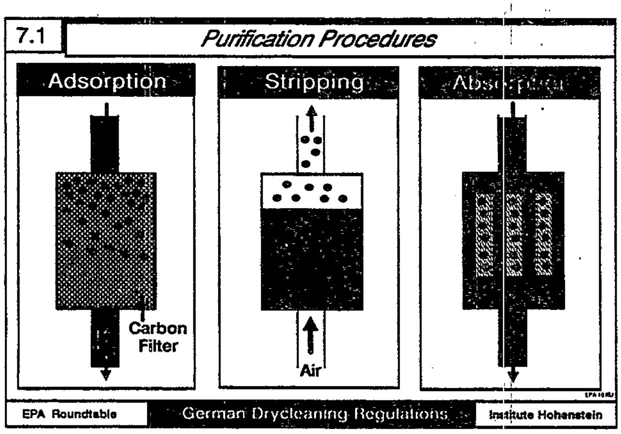
Training	*External Inspection*
• Training and examination of designated plant personnel in environmental protection by a training institute (Corresponding course). • Annual training in the plant by the manager.	Once a year: • Function and calibration of PCE measurement devices. Every second year : • Compliance with Water Protection Law.

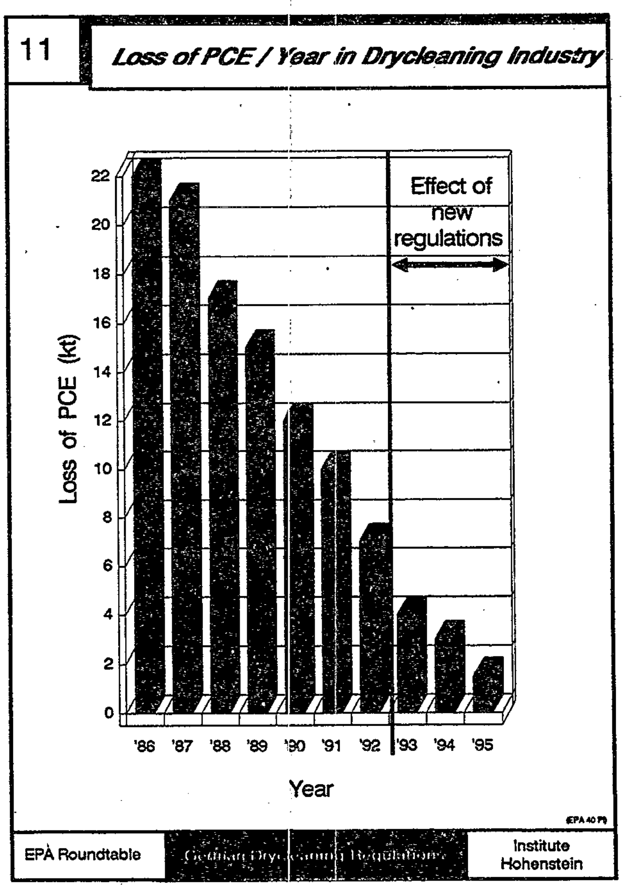
Source: Institute Hohenstein.

the owner or the manager of the plant. Once a year the measurement devices for perc must be tested for proper functioning and calibration. Every second year an inspection is required to ensure compliance with perc regulations and with the water protection laws.

Appendix

The following materials were submitted for the roundtable by Dr. Kurz, but were not referred to specifically in his presentation.





Evaluation of "New Generation" Drycleaning Equipment

Walther den Otter

TNO Cleaning Techniques Research Institute

Mr. den Otter is reseach manager and senior advisor at the Cleaning Techniques Research Institute TNO in Amsterdam, where he is developing the Dutch Internal Environmental Care System for the drycleaning and laundry industry. He is also developing cleanup methods for soil and groundwater pollution. Mr. den Otter holds an engineering degree in physical chemistry from the Technical College in Amsterdam and has published over 25 papers concerning the environmental effects of the drycleaning industry.

Introduction

The 5,000 researchers at the Cleaning Techniques Research Institute (TNO) in Holland work on a variety of fundamental and applied projects in this small, densely populated European country of 15 million inhabitants. The Institute TNO has a lot of experience working with Dutch industries to solve their problems and to develop new technologies.

The drycleaning branch covers 600 unit shops and 30 larger firms, most of which are laundry companies, throughout Holland. Since the late 1970s, the institute's drycleaning environmental projects have included not only research, but also advising and strategic planning. As a result of our contact and positive relations with the Dutch government, the Institute TNO was one of the first national branches to push through new environmental regulations (the General Administrative Drycleaning Order, GADO) and to develop an Internal Environmental Care System.

Drycleaning machines, the focus of just one aspect of the institute's work, is covered in this presentation. It includes results of various tests of emission-reduction apparatus, along with a perchloroethylene (perc) balance and the results of a "new generation" machine called the BöWe P450 with Consorba. Also covered is the correlation between leakages and vapor concentrations, suggestions for drycleaners, and a discussion of the new Internal Environmental Care System.

Emission Reduction Apparatus

The goal of Holland's new environmental regulation, the GADO, is to lower the level of solvent consumption and exposure to workers and residents living near a drycleaning operation. With a no-effect level of 136 mg/m^{3*} and a safety factor of 50, the institute's official toxicologists determined that the emission level should be kept under 2.5 mg/m^3, with a maximum peak of 25 mg/m^3. Since the odor threshold for perc—1 mg/m^3—is critical, GADO sets the maximum emission level for existing unit shops at 2.0 mg/m^3, and at 1.0 mg/m^3 for new shops, with the same maximum peak level for both—25 mg/m^3 for up to three minutes.

The maximum solvent loss is set at 3 percent, based on the weight of cleaned garments and on the terms of maximum emission concentration of 100 mg/m^3 with a three-minute maximum of 25 mg/m^3.

Table 1 shows different apparatus with their effects. Note that when solvent losses are kept below 3 percent, emissions are reduced 25 percent compared to a machine with no apparatus. However, up to three times as much energy is required for such apparatus. When deciding how best to protect the environment, a balance must be found between energy savings and emission reduction.

Perc Balance

Figure 1 shows a sketch and material balance for both a machine with an internal deepcooling system (Scheme 1) and a machine with an external active carbon recovery system (Scheme 2). In general, the machine with the deepcooling system consumes less

*1 ppm = 6,890 μg/m^3 or 6.89 mg/m^3

Table 1. Losses of perc solvent in drycleaning machines with various emission reduction apparatus.

Type of emission reduction apparatus	Solvent loss	Emission reduction	Consumption electricity	Consumption steam
No apparatus	10-12%	100%	100%	100%
Environmental valve	6-7%	60%		
Waterlock	5-6%	50%		
Active carbon recovery	4-5%	40%		++
Deep cooling without heating pump	3-4%	30%	155%	80%
Deep cooling	3%	25%	225%	40%
Deep cooling + special active carbon	2-3%	20%	300%	40%
Deep cooling + special active carbon + powderless filter	0.5-1%	10%		

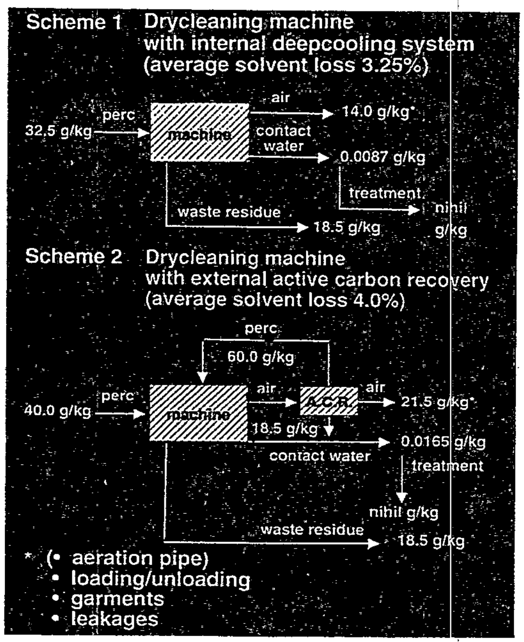


Figure 1. Various drycleaning equipment and emissions levels.

energy than the one with only a carbon recovery system. The amounts of the incoming solvent, after entering the machine from the left, are shown as the solvent flows into the compartment air, the wastewater, and then the waste residue. The solvent left in the waste residue, rather than entering the environment, is recycled by a specialized firm, as required by Dutch law. Thus, most of the solvent is lost in the compartment air where it decomposed with a half-life value of a few months.

The "New Generation" Drycleaning Equipment

Table 2 shows the effect on workers of a new-generation drycleaning machine called P450 BöWe with Consorba. The concentrations are low because they were measured directly above just-unloaded drycleaned garments, which are difficult to get dry. Such measurements must be taken very quickly, as there is no mass flow coming from the garments. Soon after the garments are removed, the measured concentration levels dropped dramatically, and thus show no indication of the drying effect.

As a base, the Institute TNO set the target value at less than 50 ppm, as measured above just-unloaded drycleaned garments. Achieving this target value would indicate a proper drying effect expected in a workplace with proper ventilation where perc vapor concentrations are normally between 5 and 10 ppm.

Tables 3 and 4 show perc concentrations in the workplace and during finishing. As expected, these concentrations were very low:

- During finishing, which takes 15 minutes—2 to 12 ppm perc
- In front of the drycleaning machine—3 to 7 ppm

Table 2. Perc vapor concentrations in front of a new-generation drycleaning machine (P450 BöWe with Consorba).

Type of garments	Load factor	Perc vapor concentration in ppm*: loading (20 sec)	unloading (45 sec)	in drum	above garments
Men's clothing	85%	28.9	25.9	83	14
" "	110%	33.3	29.0	74	48
Rain wear	60%	35.1	26.5	97	29
Quilted rainwear	60%	37.9	44.2	106	60
Sleeping bags	5 pieces	42.0	37.6	180	40

Table 3. Perc vapor concentrations during finishing using a new-generation drycleaning machine (P450 BöWe with Consorba).

Type of garments	Number	Finishing time in minutes	Perc vapor concentration in ppm*: average	variation
Raincoats	8	15.3	2.0	1.5-2.9
Jackets	15	15.6	11.6	6.7-25.6

Table 4. Other measurements of perc vapor concentrations in workplace using a new-generation drycleaning machine (P450 BöWe with Consorba).

Place in working room	Measuring time	Perc vapor concentration in ppm*
1 meter for P450	90 minutes	2.9-6.7
Behind P450	short, indication	<5
Above P450 (area around ventilation pipe)	during loading/unloading	10
In Consorba	short, indication	under; 10 and above: 15 ppm

* 1 ppm = 6.7 mg perc/m3

- Behind the machine—less than 5 ppm
- During loading and unloading, which takes up to two minutes every 45 minutes—10 ppm

In short, with such new-generation machines, values between 5 and 10 ppm easily can be reached in a drycleaning shop.

Leakages and Vapor Concentrations

When workers do not take environmental and safety precautions, the low concentration levels cited above are not attainable. The human factor always must be taken into account.

To minimize loss of solvent, the use of refrigeration and absorption technology must be accompanied by good management techniques. Employee training must include clear instructions and procedures for using the equipment. Workers must know what to do in case of equipment failure and understand basic operating, checking, maintenance, and troubleshooting techniques. The equipment must be checked regularly for potential leaks of either vapor or liquid.

The Institute TNO does not have the measurement technology to measure the correlation between leakages and perc vapor concentrations from the new-generation machines. However, based on data from old machines, the Institute has found that the more leakages a drycleaning machine has, the higher the perc vapor concentrations in the workplace. Figure 2 shows the correlation—based on hundreds of measurements—between leakages and perc vapor concentration of controlled machines in four categories, as well as measurements taken from behind the machine and in the workplace. Notice that the workplace vapor concentrations are lower, since the measurements are taken farther from the machine.

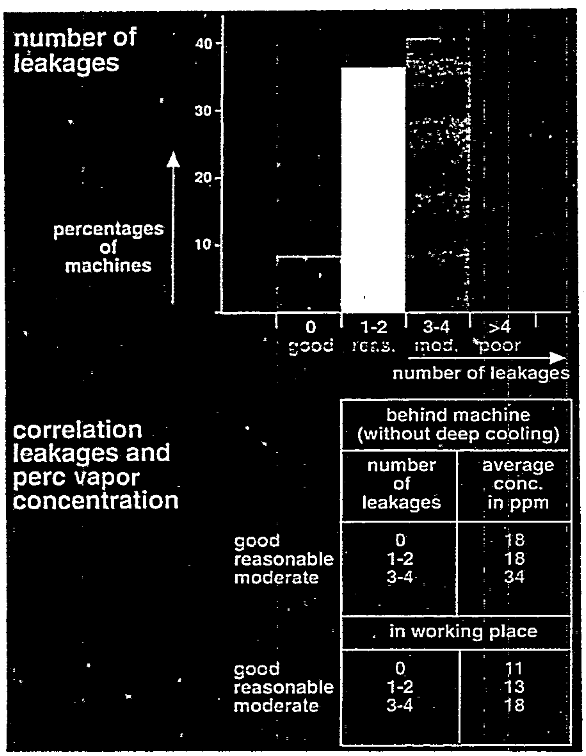


Figure 2. Perc vapor relative to machine leakage.

Indications are that the correlation between leakages and perc concentrations in regard to new-generation machines is less of an issue: first, the new machine's more effective drying process leaves less perc in the cleaned garments; second, the computerized controls of these machines include pressure and temperature sensors that allow early detection of operational failure.

The best way to monitor leakages is to keep a logbook for tracking solvent consumption and leakage checks. Such a logbook is required by the Internal Environmental Care System.

Advice to Drycleaners

Table 5 lists advice Institute TNO gives Dutch drycleaners to ensure a safe and environmentally acceptable cleaning process.

Table 5. Recommendations for drycleaning operations from Institute TNO.

Safe operator action

- Follow the operating and maintenance instructions provided by the manufacturer of machine
- Maintain the cleaning machine regularly
- Switch the machine off during maintenance work and when the machine has to be cleaned
- Run an automatic rather than a manually-operated cleaning program
- Do not open the loading door during cleaning and drying
- Do not skip any safety regulations (through shortage of time)

Particular attention

- Good drying process
- Machine, both design and maintenance
- Emission restriction device
- Removal of distillation residue
- Topping of the cleaning machine
- Stain removal
- Adequate workplace ventilation

Internal Environmental Care System

In addition to good technology and state-of-the-art machines, the human factor always affects the drycleaning process. Good environmental protection cannot be achieved simply by making capital investments. It results ultimately from making people environmentally aware. Appropriate training fosters better work involvement, higher productivity, and improved product quality. In the end, how the drycleaning machines are operated may be a major environmental factor.

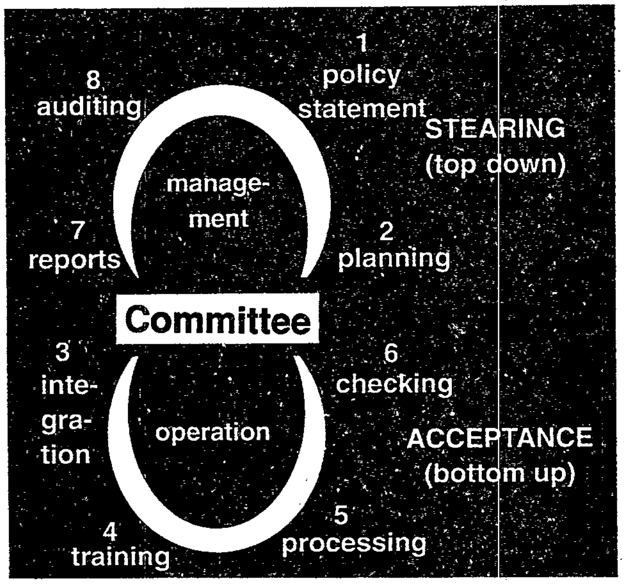


Figure 3. Dutch Internal Environmental Care System.

The Internal Environmental Care System calls for firms to set up their own control system to include regular checks of machines along with registration and audits (Figure 3). The government's role, then, will be to monitor this system, rather than to enforce rules, permits, and laws. All Dutch industries—not just drycleaners—are required to implement such an "auto-control" system by 1995.

The system consists of eight elements that are closely related:

- Policy statements
- Planning
- Integration
- Training
- Process management
- Checking
- Reports
- Auditing

The system addresses problems of emissions, air/water/soil pollution, noise, waste, odor, and the consumption of energy and materials.

Fiber-Solvent Interactions

Hans-Dietrich Weigmann, Ph.D.

TRI/Princeton

Dr. Weigmann is associate director of research at TRI/Princeton, in New Jersey, where he has served as a scientist for over 31 years. He has extensive experience in fiber-solvent interactions, a subject area in which he has been widely published. Dr. Weigmann holds degrees in organic chemistry from the University of Heidelberg and the Technical University Aachen, Germany.

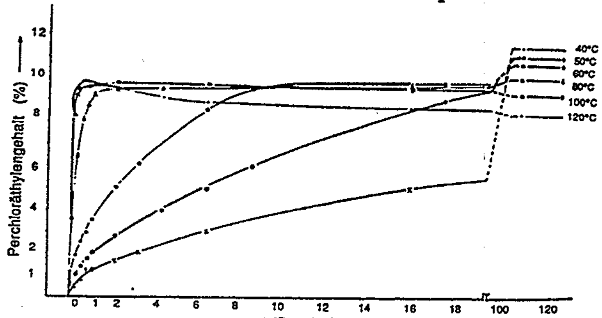
TRI is a nonprofit organization loosely associated with Princeton University. TRI has a joint polymer materials program, and we have been active in exploring interactions between polymeric fibers and solvents for quite some time. We approached this research from a specific point of view originally. We looked at questions such as, What does a solvent do? How does it penetrate? What properties are required for a solvent to penetrate a particular fiber? We wanted to look at these questions from a dying point of view, and from a finishing point of view, and now we are looking at them from a drycleaning point of view, which involves approaching issues from the opposite perspective. That is, how can we avoid penetration of the fiber and yet achieve the cleaning function that is required of the solvent?

In drycleaning we are removing essentially particulate and oily substances from the surface, and we wish to avoid penetration of the solvent into the fiber structure itself. As we all know, with the current equipment and practices we cannot avoid penetration; we cannot avoid the fact that there is residual solvent in the fabric that could conceivably give us problems, especially if regulation progresses the way it has been lately. So I would like to look at what is involved in absorption/desorption of solvents—the fiber-solvent interactions. What determines the parameters? When we look at solvents, what properties or conditions will help us avoid this kind of penetration? And I'm going to restrict my remarks to polyester (PET) and perchloroethylene (perc).

It is well known that in the process of drycleaning a rather effective physical separation of solvent and fabric occurs. Then in the drying phase desorption from the fabric occurs. There are actually two phases involved here: One where the solvent is removed from the surface, the surface head or solvent head in the interstices of the fabric. Here the solvent is removed by evaporation. The parameters involved here are the heat of evaporation of the solvent, the solvent vapor pressure under the conditions of removal, the solvent air diffusion at the conditions of dry (of the removal process), and the velocity of an airstream that is generated.

The second phase of interest is much more difficult to analyze. The eventual time required for solvent removal in the first phase can be predicted from the properties and from the parameters and conditions of removal. The second phase involves solvent removal from the fiber itself; that is, internal diffusion of solvent to the surface where it is then removed. So here we are looking at solvent diffusion within the polymer. There is a considerable amount of information and a considerable amount of literature available that deals with absorption and desorption of perc in PET.

Figure 1 shows the sorption, in this particular case, of perc by PET as a function of time, where the temperatures of the conditions of sorption are 40 to



Source: Bredereck and Koch, 1974.

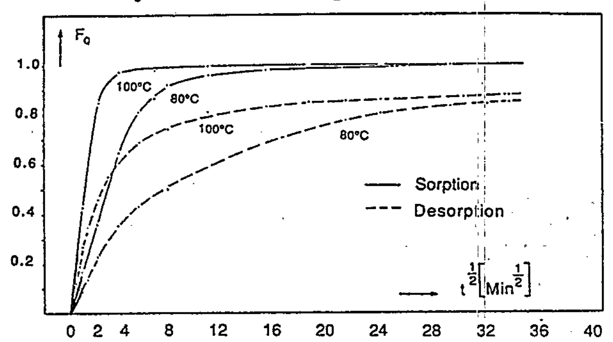
Figure 1. Temperature dependence of perc sorption by PET.

120°C. Granted we are not talking about 120°C or anywhere near it in drycleaning operations, but this is the way these data have been collected. As the figure shows, there is almost instantaneous equilibration at the high temperature and a very slow sorption, which eventually reaches an equilibrium conditions at 40°C. Even at 40°C, which is well below the glass transition temperature of the polymer, absorption occurs. That is because as the solvent front moves into the fiber, it lowers the glass transition temperature of the polymer. Under these conditions—40°C—some uptake in the 1 to 2 percent range does occur.

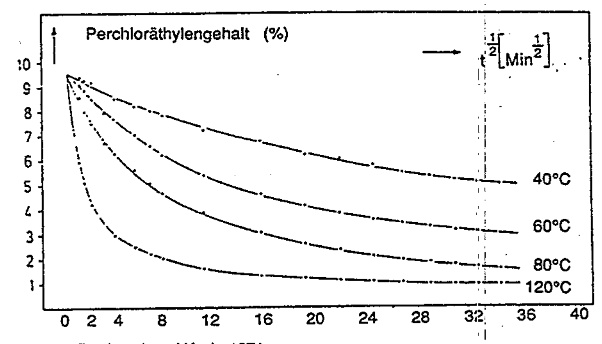
Of course, if wet material is subsequently used, and it is heated in order to remove the solvent, we also drive the solvent into the polymer itself. So we have a situation where in the interest of speed of removal we actually cause an effect that is undesirable.

In terms of sorption versus desorption, in Figure 2, where the sorption is at 80 and 100°C, rapid equilibration results. When the solvent is desorbed at 100°C, it is considerably slower, but still reasonably fast. At 80°C that difference is much higher, and as we move away from the glass transition temperature of the polymer and the concentration this difference in the rate of absorption/desorption becomes progressively wider and it becomes more difficult to remove solvent from the interior of the fiber.

Figure 3 shows an equilibrium condition when the material is treated eight hours at 60°C. We actually intentionally looked for an equilibrium condition and



Source: Bredereck and Koch, 1974.
Figure 2. Sorption-desorption of perc from PET at 80 and 100°C.



Source: Bredereck and Koch, 1974.
Figure 3. Desorption of perc from PET after treatment for 8 hours at 60°C.

now we look at the effect of temperature on the desorption rates. As shown, at 40°C, after what is roughly 20 hours, only 50 percent of the perc has been removed. Even at 120°C, although rapid desorption is reached initially, as the final value is approached, desorption becomes progresively slower and then it appears that total removal of solvent from the polyester is never achieved. Conceivably, this is because the solvent at these high temperatures is entrapped in the fiber structure.

At room temperature the situation is much worse, of course. In Figure 4, the fibers were treated for one hour at 80°C, at a draw ratio of 4.1. The fibers are fully drawn polyester yarns. As shown, at approximately 50, 60, 80, 100 days, only 40 percent of the solvent has been removed. The solvent comes out very slowly, which is a problem from the point of view of desorption. It is a benefit, on the other hand, if the perc has penetrated the structure considerably. Looking at room temperature desorption, we know that this desorption is very slow. The accumulation of solvent in a closet or in a garment bag, for instance, is approaching equilibrium values at a very, very slow rate.

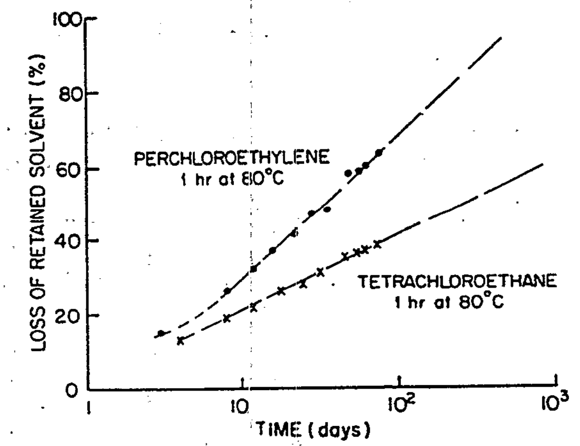


Figure 4. Storage loss of solvent retained by polyester yarns (draw ratio 4.1) after treatment in perc and tetrachloroethane for 1 hour at 80°C.

Now the questions are, How can we predict what solvents will penetrate the structure? And what solvents will not penetrate the structure? These questions are considered from the point of view of how do the solvents enter the structure, rather than from the point of view of drycleaning effectiveness of the solvent. The solvents that do not penetrate, or those that have considerable difficulties in penetrating will have to be looked at to determine their drycleaning capabilities.

Figure 5 is a plot of the glass transition temperature—the shift in glass transition temperature of polyester as a function of the solubility parameter of the solvent. The figure shows the shift down to a very low glass transition temperature, and shifts of up to 220°C. Although these data were accumulated by

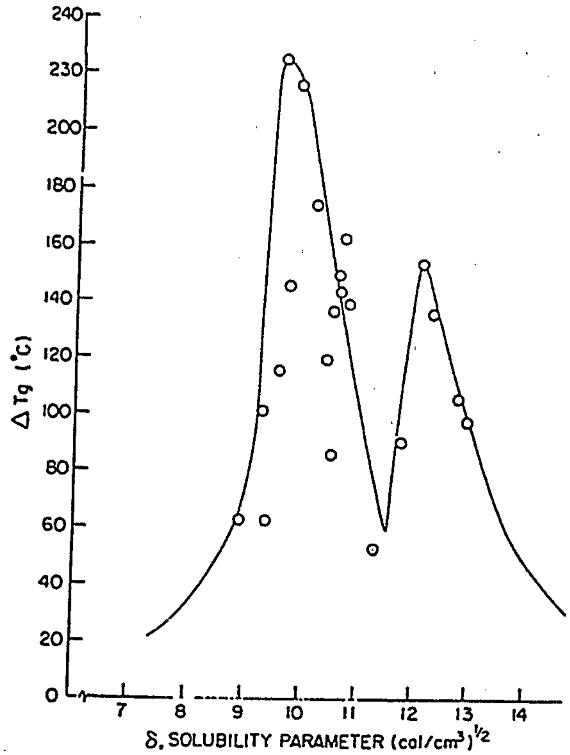


Figure 5. Glass transition temperature relative to the solubility parameter.

dynamic shrinkage measurements and then extrapolated, it appears that they have some validity. Note the bimodal distribution of the delta TG. The glass transition temperature of the polymer itself is 80°C, as we know, which means that on both sides the 80°C value is approached. The solubility parameter of PET is 10.7, and our maximum interaction levels are considerably removed from this value.

We have to look at polyester under these conditions as a copolymer consisting of aromatic and aliphatic moities that interact with the solvent in their own way. The aromatic branch here is interacting on the low level of the solubility parameter and the aliphatic with the polarity of the solvent entering into the picture.

Briefly, Figure 6 depicts equilibrium thermodynamics through which the solubility parameter can be determined. This parameter is described by the cohesive energy density of the material, and the heat of mixing is given by a value where we have the polymer and the solvent (Table 1). As soon as the two are very close or identical, we have a maximum of interaction.

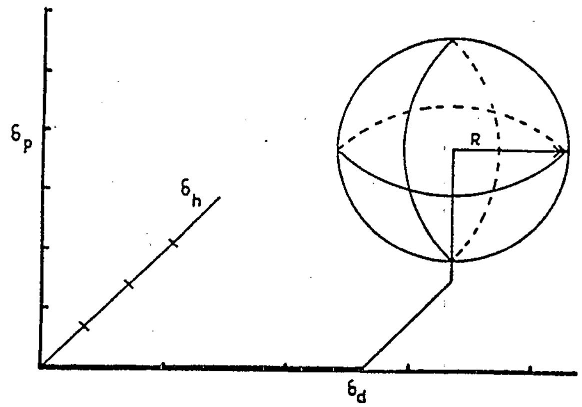


Figure 6. Sketch of typical volume of interaction for Hansen's three-dimensional solubility parameter concept.

Table 1. Solubility parameter theory.

Heat of Mixing ΔH_m

$$\Delta H_m = V_m \left[\left(\frac{\Delta E_1}{V_1} \right)^{\frac{1}{2}} - \left(\frac{\Delta E_2}{V_2} \right)^{\frac{1}{2}} \right]^2 \phi_1 \phi_2$$

Solubility Parameter δ

$$\delta = \left(\frac{\Delta E}{V} \right)^{\frac{1}{2}}$$

Three Dimensional Solubility Parameter

$$\delta = \sqrt{\delta_d^2 + \delta_p^2 + \delta_h^2}$$

Source: Hildebrand, 1950; Scatchard, 1931.

References

Bredereck, K., and E. Koch, 1974. Melliand Textilber, 55, 157.

Hansen, C.M., 1969. Ind. Eng. Chem., Prod. Res. Dev., 8, 2.

Hildebrand, J.H., and R.L. Scott, 1950. *Solubility of Electrolytes*. New York: Reinhold.

Ribnick, A.S., and H.-D. Weigmann, 1973. Textile Res. J., 43, 316.

Scatchard, G., 1931. Chem. Rev. 8, 321.

Operating Drycleaning Equipment to Minimize Exposures

Jack D. Lauber
Division of Air Resources
New York State Department of Environmental Conservation

As a staff engineer for the New York State Department of Environmental Conservation, Division of Air Resources (Bureau of Application and Permitting), Mr. Lauber manages hazardous waste disposal projects and coordinates the department's drycleaning industry regulatory program. He is a professional engineer and a diplomate in the Academy of Environmental Engineers with 30 years of experience in the environmental area. He holds a B.A. in chemical engineering from New York University.

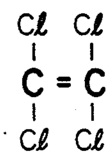
In the State of New York there have been some very serious problems with drycleaners impacting the environmental quality in residential apartments and also some general air pollution problems in urban areas. Problems have been most pronounced in New York City, where there has been severe contamination of apartments as well as other ancillary air pollution problems concerning uncontrolled or poorly controlled emissions of perchloroethylene (perc) from drycleaning operations.

Judy Schreiber, from the State Health Department, addresses residential exposure in one of her presentations. My focus is on the tools needed to properly control emissions from drycleaners, recognizing the ranges in technology. It is generally agreed that proper operation and maintenance is particularly important for controlling emissions, along with the selection of appropriate control technologies. Thus, I'd like to present an overview of certain state-of-the-art control measures that we at the New York State Department of Environmental Conservation believe are necessary to properly control emissions from drycleaning equipment and offer our perspective on the issue based on what we have discovered in our investigations of drycleaning operations in New York State.

Table 1 lists a selection of environmental standards for perc emissions. The Occupational Safety and Health Administration (OSHA) standard limits exposure to perc to eight hours at 25 ppm. OSHA also has certain other standards, such as the 200 ppm short-term exposure limit. The Germans are using 10 ppm as an occupational standard for perc. Generally speaking, perc emits a detectable odor when the concentration is about 50 ppm; however, some people can smell perc at lower levels.

Table 1. Selected perc exposure standards.

PERC, (TETRACHLOROETHYLENE)



? Potential Human Carcinogen

OSHA PEL ——— 25 ppm
GERMAN ——— 10 ppm

1 ppm = 1 inch in 16 miles
= 1¢ in $10,000.

Odor Level ——— 50 ppm PERC.

- NYSDEC AGC for PERC.
(NESCAUM)

1.2 $\mu g/m^3$ = 0.16 ppb

1 ppb = 1 inch in 16,000 miles
1¢ in $10,000,000.

We have proposed a very stringent ambient level for perc emissions. The New York State Department of Environmental Conservation ambient guideline concentration is 1.2 $\mu g/m^3$, which is .17 ppb on an annual average. This standard is based on cancer risk and was developed with guidance from the Northeast States for Coordinated Air Use Management (NESCAUM) group. There is also the New York State Health Department's indoor air guideline, which is identical to the German guideline of a 100 $\mu g/m^3$. This level is suggested as a standard that minimizes risk in residential settings.

The question is, How did we set this level? It is our experience that most of the problems with drycleaning equipment are due to fugitive emissions from the loading door and from other point sources. There are many situations where at the end of the cycle even the best refrigerated condenser machines give off emissions of 500 to several thousand ppm, depending on the condition of the refrigerated equipment. We believe that ventilation standards have to be established to properly contain these emissions.

Local ventilation must be controlled so that whenever the door to a drycleaning machine is opened there is an inward flow of air. We are using the 100 feet per minute guideline suggested by the National Fire Protection Association (NFPA), the State of Michigan, and others, and we believe that this is an effective standard for minimizing exposures in the work room, as well as ancillary emissions—fugitive emissions that can impact on residential areas.

We have conducted extensive emission testing using portable photoionization instruments. We have found that when there is effective equipment maintenance, reduction of leaks have been reduced, gaskets are in good condition, and ventilation is effective, perc exposure can be minimized. In general, we have found that residual levels of perc can be kept to 1 to 2 ppm in the work room with effective ventilation and process controls. Recommended emission reduction measures are listed in Table 2.

Isolation of the drycleaning equipment and adequate general ventilation is particularly important. Guidelines used by the State of Michigan and recommended by NFPA suggest an air change in the work room every five minutes. In one case we studied, a drycleaning operation in New York City was releasing significant perc emissions into an apartment above. One of the basic control approaches recommended was to enclose the drycleaning operation and build a small room or enclosure. Also, it was recommended that the air be vented through one duct and exhausted through another, achieving an air exchange in less than 5 minutes. I understand that the system as eventually set up was overdesigned and that the air is being exchanged about every 2.5 minutes. Any leaks of perc that occur, or any fugitive emissions, are exhausted immediately to the outdoor air and cannot leak into nearby apartments.

Also, diffusion-resistant materials were used in making the enclosure. The materials consist of polyethylene sandwiched between foam insulation. Perc emissions had been tens of thousands of $\mu g/m^3$ in the work room from this uncontrolled drycleaning operation. The emissions have been progressively reduced very significantly with these control measures—by several orders of magnitude.

There are two types of ventilation: general exhaust ventilation of a work enclosure, and local exhaust ventilation of the drycleaning machines. A new type of control device has been pioneered in New York City that actually is adapted to a refrigerated condenser machine. This system controls perc by exhausting the machine at the cage. The door is opened at the end of the cycle to exhaust the perc vapors. The gas stream can be vented to a dual-carbon absorber and emitted to the outdoors. Tests of such a facility have shown concentrations of up to 500 ppm perc entering the carbon adsorption system and approximately 1 ppm leaving.

We believe that the German perc emission guidelines are appropriate, and we are suggesting an emission standard of 5 ppm, which is very close to the German emission concentration limits, can be met with this type of control system (Table 3). With a

Table 2. Suggested perc reduction measures.

1. Repair Leaking Gaskets, Hoses, Machine Leaks
2. Improve Garment Aeration, Don't Overload Machine
3. Monitor PERC Solvent Mileage 20,000 (good) – 50,000 (ideal) Lbs. Fabric/Drum
4. Improve Separation of PERC & Water From Condenser
5. Improve Filter Sludge Recovery
6. Check All Local Exhaust Systems For Leaks
7. Check Pre-filter & Carbon Adsorber (Sniffer) For Good Operation. Strip Daily, Check PERC Conc. Often (<25 ppm PERC Feasible). Problem if Much Greater.

Table 3. Efficiency of suggested emission control approaches.

EMISSION SOURCE	TYPE OF CONTROL	CONTROL EFFICIENCY (%)
Process	Carbon Adsorb.	95
Vent	Refrig. Conden.	85/95
	Refrig. Cond. & Carbon Adsorb.	99+
Fugitive	Proper Oper. Pract.*	Unknown
	Leak Detect. & Rpr.	Unknown
	Dry-to-Dry Mach. Use	50

*Proper operating practices (e.g., covering solvent containers, keeping lint traps clean, minimizing open door times and adhering to machine cycle times) refrigerated condenser machine, the system is only on when the door is open and when the exhaust is operating, which is only a short cycle of a few minutes per machine door opening.

Another control concept involves transfer machines. The vapor containment system for a transfer machine uses a total vapor enclosure made of clear vinyl. With 100 feet per minute air velocity coming in through the curtain there is complete ventilation of the entire transfer machine operation enclosure. Only one such system has been installed in New York State to date. We tested this device system on several occasions, and found that it was very effective. We measured perc concentrations of up to 50 ppm during air transfer inside the vapor containment enclosure, and 1 to 2 ppm in the work room. This system may have promise for controlling emissions from transfer machines in existing residential areas.

I also want to discuss the environmental regulation that we are currently drafting. Similar to EPA, we are including the enclosed refrigerated condenser and the dry-to-dry machine with a carbon absorber as the best available control technologies. The refrigerated condenser, carbon absorbers, and azeotropic devices with carbon absorbers are the principal control technologies.

For existing sources we are also proposing high-efficiency carbon adsorption systems with emissions of 5 ppm or less. We believe it is important to have strict control of a carbon adsorber in order to meet our stringent ambient guideline value of 1.2 $\mu g/m^3$ of perc on an annual average. Our proposed emission standard is very close to the German emission standard. We also believe that all drycleaning facilities should have 100 feet per minute of inward local exhaust velocity through the machine door opening. This is a very important step for controlling fugitive emissions from the loading door. We also believe that more stringent control provisions are necessary for drycleaning operations adjacent to residences and other businesses, especially food service establishments. In such cases, general exhaust ventilation with an air change every five minutes should be required along with a vapor barrier. In general, we have found that an adequate vapor containment system and local and general exhaust ventilation systems can effectively control perc emissions, if the operator maintains and operates equipment properly.

Appendix

The following tables and figures were submitted for the roundtable by Mr. Lauber, but not referred to specifically in his presentation.

BENEFITS OF USE OF BACT DRY CLEANING TECHNOLOGY AND OPTIMUM OPERATION

- Lower Solvent Costs
- Reduction in Worker Exposure
- Reduce Liability For Toxic Emissions

CONTROL OPTIONS

TRANSFER

99% Vent Control (very difficult)
95% Vent Control (immed. or gradual)
85% Vent Control
No new transfer machines

DRY - TO - DRY

99% Vent Control (has been achieved)
95% Vent Control

EMISSION SOURCES

VENTS

Washer/Extractor — Vented after wash cycle

Dryer — Vented during aeration and after drying cycle

FUGITIVE EMISSIONS

- equipment leaks
- storage
- exhaust damper malfunction
- residual solvent in clean garments
- "wet" garment transfer

CONTROL TECHNIQUES

1. PROCESS VENT CONTROLS
   - Carbon adsorber
   - Refrigerated condenser
2. FUGITIVE CONTROLS
   - Emission & control data lacking
   - OSHA PEL to 25ppm
3. REPLACEMENT of Transfer Machines With Dry-to-Dry Machines
4. BACT, MACT
   - Dry-to-Dry refrigerated condenser no vent machine with machine door local exhaust

   or

   Same with internal aeration & supplemental carbon adsorber
5. SOLVENT SUBSTITUTION ?
   - petroleum distillates (fire hazard)
   - CFC 113 (none yet acceptable, CFC ozone probs.)
   - 1,1,1-TCA (solvability, probs. ozone depletion)
   - HCFCs 123, 141 (further evaluation necessary by IFI, etc.)

MACHINE SIZES

SECTOR	RANGE OF MACHINE SIZES (lbs. of clothes)
Commercial	15 – 100
Industrial	140 – 250
Coin-operated	
Self service	8 – 12
Plant operated	

DESCRIPTION OF PERC DRY CLEANING INDUSTRY

Types of Dry Cleaning Equipment

- **Transfer** - Separate Washer & Dryer; Manual Clothing Transfer Step
- **Dry-to-Dry** – Washer & Dryer Combined: No Transfer Step

  UNREFRIGERATED - vented to carbon adsorber (sniffer)

  REFRIGERATED CONDENSER -
  - no vent (BACT)
  - vented at 100 fpm to supplemental carbon adsorber (MACT ?)

PROPOSED PART 232

NEW ENCL. REFRG. CONSENSER OR DRY TO DRY + CARBON ADSORBER, OR AZEOTROPIC DEVICE

EXISTING - HIGH EFFICIENCY CARBON ADSORBER - 5 PPM

GERMAN STD. - 3 PPM

ALL - 100 FPM LOCAL EXHAUST VELOCITY

WITH ADJACENT RESIDENCES AND FOOD SERVICE

GEN. EXHAUST VENT - AIR CHANGE PER 5 MIN. + VAPOR BARRIER

Dry Cleaning Facility Compliance Measures and Costs

Compliance Measure	Capital Cost (includes installation - 1991 dollars)
Installation of a state of the art totally enclosed refrigerated condenser dry-to-dry machine.	$40,000-$50,000
Addition of a total vapor contaminant system to an existing transfer type machine including a carbon absorber.	10,000-12,000
Adding a carbon absorber to an existing dry-to-dry machine.	6,000
Adding an azeotropic control system including a carbon absorber to an existing dry-to-dry machine.	7,000
Adding an exhaust system and carbon adsorber canister to a refrigerated condenser machine (supplemental control system).	2,500-3,500
General ventilation of workroom (air change every five minutes) and vapor barrier, for facilities near residential areas.	1,000-2,000

DRY CLEANING INSPECTION FORM

INSPECTED BY ______________________________
DATE ______________________________
FIRM ______________________________
ADDRESS ______________________________

1. Brand of Machine: ______________________________

2. Type(s) of Machine:
   A. Transfer ____________
   B. Dry to Dry ________Vented; ____Non-Vented ___
   C. Refrig. Condenser ____________
   D. Azeotropic Solvent Recovery System ________
   (Used with Transfer or Dry to Dry Machine.)

3. Number of Machines: ______________________________
   Sector Type:
   A. Commercial ____________
   B. Industrial ____________
   C. Coin Operated ____________

4. Capacity ____________ lbs/machine

5. Dry Cleaning Solvent Used:
   A. Petroleum ____________
   B. Tetrachloroethylene (PERC) ____________
   C. Other(specify, e.g. Freon, TCTFE) _____
   ____
   D. Total Quantity of Solvent
   Used/Year ____________ (lbs)
   E. Total Quantity of Solvent Type Hazardous
   Waste Disposed/Year ____________ (lbs)

6. How Are The Dry Cleaning Machine Emissions Vented and Controlled?
   A. Vented without Control ____________
   B. Vented to outer air w/carbon-adsorber ________
   - Above Roof ____________
   - Through Wall or Window ____________
   C. Vented to carbon adsorber, and exhaust recirculated to room
   ____
   D. Minimum Inward Air Velocity (Ft/Min)
   - Through Machine Door(s) ____________

- Through Exhaust Hood Openings ______________
  (Slot Hoods should achieve an equivalent 100 FPM at furthest machine door opening point)
- Smoke Bomb Test (Yes _____ or No _____)

7. Vapor Condenser:

   A. Water cooled condenser (e.g. For Transfer, Dry To Dry or Azeotropic Unit)
      - Gauge Temperature at Inlet (e.g. 70oF)* ______________
      - Gauge Temperature at Outlet (e.g. - 80oF)* ___________

   B. Built-in refrigerated condenser ______________________
      - Gauge Temperature of Outlet at Condenser (e.g. 40oF) _____

8. Dryer .

   A. Lint Trap Door Gauge Temperature of (e.g. 140-150oF)_________________

9. Carbon adsorber _______________________

   A. External __________________
      - Full Size Unit (.e.g Dry to Dry Machine) _________
      - Small Type (e.g. Azeotropic, Refrigerated Condenser)________
        - Number of Adsorber Units ________________
        - Series or Parallel ____________

   B. Internal (built into machine) ____________

   C. Stripping of carbon:
      - Steam _____________________
      - Hot Air ___________________

   D. Type of Adsorber Prefilter:
      - Urethane Foam _______________________
      - Other (specify) _____________________
      - Frequency of Replacement ____________

10. General Ventilation of Workroom (Axial or Propeller Type Fans)

	Number	Size (Dia.")	Rating (CFM) of Fan
A. Number and size of exhaust fans in room	_____	______	_________

*Measured At Water Lines of the Condensing Coil on the Dryer

B. Location:

- Ceiling ______________ ______
- Window ______________ ______
- Wall ______________ ______

C. Makeup Air Inlet (yes/no) ______________

Type: Door, Window, Louver ______________

D. Calculated Air Changes = (Volume of Room/Total CFM Exhaust = Minutes Per Air Change) = ________ Min.

11. Maintenance and Operation

A. Equipment Leaks (yes/no) ______________

Where? (e.g. water separator, still)__________

B. Solvent Storage Tanks and Containers (covered/uncovered) ______________

C. Machine Exhaust Damper (operating properly)

(Yes or No)______________

Leak Test ____Pass ____Fail

D. Carbon Adsorber Stripping cycle

- (how often? e.g. daily) ______________
- ________ lbs clothes/lb carbon (3.0 recommended For Full Size Unit)
- Steam Pressure (PSIG) ______

E. Significant residual solvent in garments (yes/no) ________

F. Filter cartridges drained for 24 hours (yes/no) ________

- Reclaimed in still (yes/no) ______________

G. Perc/Water separator fugitive emissions (yes/no) ________

H. Machine Lint Filters Replaced Regularly (yes/no)________

I. How are Spent Solvents, Filters, and Other Wastes Disposed? ________

J. How is Waste Water Discharged?

- Sewer ________ Untreated ________

Treated ________

- Evaporated in Workroom ________

12. Monitoring Results

A. Instrument Used (e.g. HNU, Photovac, etc.):______________

____

B. Average Workroom PERC Air Concentrations (ppm):

- In front of machines ______
- Behind machines ______
- At Water Condenser Separator ______
- At Still Separator ______
- At machine door when opened ______
- At pressing station ______
- At carbon adsorber exhaust ______
- Outside at exhaust fan discharge ______
- Other (describe) ______

13. Is there any occupied space directly above or adjacent to the Dry Cleaner, ex., office, living space, restaurant, etc.? (explain) ______

14. Type of ceiling in Dry Cleaner ______
Diffusion Resistant Construction (yes/no) ______

15. Are there any openings in the ceiling, ex., missing ceiling tiles, pipe chases, etc.? (explain) ______

16. Odor intensity in Dry Cleaners
    - High ______
    - Medium ______
    - Low ______
    - None ______

17. Remarks

JDL/lms
4/30/92
90-1/2-167

Roundtable Discussion Summary: Exposure Reduction

Discussion about exposure reduction began with several questions for Josef Kurz of Institut Hohenstein concerning the requirement in Germany for interlocks on new closed machines that prevent the door of the drycleaning machine from being opened until the perc concentration in outlet air reaches 2 g/m^3. Ken Adamson of the Drycleaners and Launderers Institute of Ontario enquired about the development of instruments to perform continuous monitoring within the cage. Dr. Kurz indicated that at first they had imported a device from the United States that cost approximately $20,000 plus an additional $10,000 to modify it. Later, a call went out to the German instrumentation industry for innovation and one has been developed that costs around $5,000.

Manfred Wentz of R.R. Street indicated that on a recent trip to Germany he had taken measurements inside the cage above the clothes and obtained readings of up to 1,500 ppm in the air. He suggested that this could indicate that the instruments are not reporting an equilibrium concentration. To truly obtain a very low equilibrium concentration, he believes that the drying and aeration times would have to be significantly increased, at the expense of machine capacity and throughput. This led to considerable discussion of the measurements reported by Dr. Kurz, which were not resolved. Participants agreed to table the debate so that other questions could be raised.

Judy Schreiber of the New York State Department of Health asked whether the Netherlands has a standard for apartments and if so what that level is. Walther den Otter of TNO Cleaning Techniques Research Institute responded that there are three standards that relate to apartment exposures: (a) 100 μ/m^3 for air leaving the shop, (b) 1 μ/m^3 for air outside the apartments, and (3) zero or non-detect for air inside the apartments. To achieve non-detect levels in apartments they must use diffusion barriers, otherwise levels of 25 to 50 ppm can be measured. Mr. den Otter also responded to Dr. Schreiber's question concerning standards for perc concentrations in food by indicating that a limit of 100 ppm or 1 µg/kg has been established.

Bill Seitz of the Neighborhood Cleaners Association questioned Dr. Kurz on the types of diffusion barriers that have been evaluated to reduce the infiltration of perc vapors into apartments and neighboring establishments. Dr. Kurz reported that experiments were conducted to determine the thickness of wall material that would be required to reduce vapor concentrations penetrating the wall from 50 ppm to 0.1 ppm. Researchers found that if conventional building materials were used the walls would have to be exceedingly thick; up to 65 cm for brick and 236 cm for plaster. Greater success was found when special coatings were applied to conventional wall material. For example, metal-containing paint and aluminum-backed wallpaper were both effective in virtually eliminating infiltration. Mr. Seitz asked if polyethylene films had been tested and Dr. Kurz answered that they had not been.

Ross Beard of R.R. Street questioned Dr. Kurz on the basis for setting such stringent regulations on drycleaning in Germany. Dr. Kurz indicated that the level of regulatory control had nothing to do with the suspected carcinogenicity of perc but rather was due solely to the classification of perc in Germany as a hazardous substance.

Bill Fisher of the International Fabricare Institute asked about the current costs for setting up a drycleaning shop in Germany or the Netherlands, given the strict regulations that have been introduced. Walther den Otter of TNO responded that newer machines that meet the regulations will certainly cost more but also they will save solvent, so there is a payback. As a means of comparison, he gave the example of solvent consumption for older vintage equipment versus new generation machines. Where the solvent cost of cleaning one kilogram of clothes was previously 1.6 Dutch guilders it is now closer to 1.0 guilder.

Steve Risotto of the Center for Emissions Control was interested in the ventilation retrofit that Jack Lauber of New York Department of Environmental Conservation had shown. He asked whether DEC had engineered the project or whether commercial firms were doing such things in New York. Mr. Lauber indicated that there were a number of firms in the New York City area performing these types of retrofits, and that the one shown was done by a private contractor.

RESIDUAL REDUCTION

U.S. EPA Research on Drycleaning Residual Reduction

Bruce A. Tichenor, Ph.D.
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency

Dr. Tichenor has 27 years of experience with the EPA and its predecessor agencies and currently directs a comprehensive research program at the EPA laboratories at Research Triangle Park, in North Carolina, for evaluating sources of indoor air pollution. He is a registered professional engineer with the state of Oregon and holds a B.S. in civil engineering and a Ph.D. in sanitary engineering from Oregon State University. Dr. Tichenor is on the ASTM's Indoor Air Committee and has published over 40 technical papers on sources of indoor air pollution.

This presentation concerns a study that was conducted about four years ago. It was carried out cooperatively with EPA's Office of Toxic Substances, which is now called the Office of Pollution Prevention and Toxics. The study had a couple of objectives (Table 1), one of which was to find out the effect that bringing drycleaned clothes—freshly drycleaned clothes—into a residential environment will have on the levels of perchloroethylene (perc) inside the home. The second objective was to answer the question of whether there is something the consumer can do—for instance, hanging the clothes outside for a time—to reduce the levels of residual perc before the clothes are brought in the home. That's what we call *airing out*.

Our approach used small environmental test chambers to evaluate the emission rates and the decay rates of perc in fabrics. We conducted the study at our laboratory in Research Triangle Park, North Carolina. In addition, EPA has an indoor air quality test house there. In other tests, we took drycleaned clothes, put them in a closet in the test house, and then measured levels of perc at various locations throughout the house. Then we did some indoor air quality evaluation using a computer model.

Table 1. Experiment for testing emissions of perc from drycleaned clothes.

Objectives:

- Determine the increase in perc in residences due to dry cleaned clothes
- Determine the effectiveness of "airing out"

Approach:

- Small chamber testing; emission rates & decay rates
- Test house experiments; bag off, bag on, "airing out"
- IAQ model evaluation

Results and Conclusions:

- Freshly dry cleaned clothing causes elevated levels of perc indoors
- "Airing out" of freshly dry cleaned clothing by the consumer is not practical due to the slow decay of the perc emission rate

Not surprisingly, we found that when you bring freshly drycleaned clothing indoors, you can measure elevated levels of perc. The other thing we found—which after this morning's presentation should also not be surprising—is that due to the very slow decay rate of perc in drycleaned fabrics, having the consumer air them out for some reasonable period of time—in our case we used six hours—is probably not worthwhile, since the decay rates that we measured were quite slow.

The technology we used to conduct this research is used to study a lot of indoor air pollutants. It involves loading small environmental test chambers into a constant temperature environment; clean air is introduced, and then we are able to measure the concentration of the pollutants coming out—in this case perchloroethylene (Figure 1). Using gas chromatography as our analytical technique, we obtain a concentration versus time profile for the outlet from the chamber. We assumed for this study that the emission rate was going to follow a first-order decay. Thus, we solved the differential equation of the mass

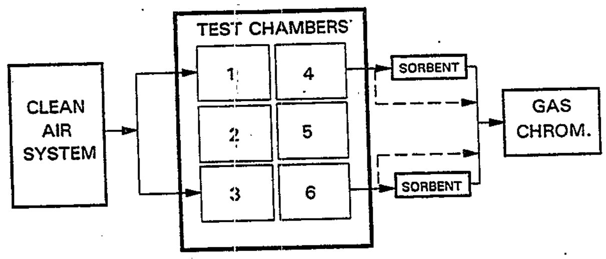


Figure 1. Small chamber (53 liters) emissions testing facility.

balance of the chamber for this emission rate (Figure 2), and then presented the data using a nonlinear, curve-fit routine (which sounds complicated but is easily accomplished on a personal computer). Figure 2 presents a portion of one of the curves from the study; it shows concentrations over a 48-hour period. The tests we conducted in the small chambers generally ran from two to five days. Out of this we calculated an initial emission rate (R-0) and a decay rate (K). It turns out that the ratio of these two rates is the total amount of emittable material; here perc residuals are given in mg/m³.*

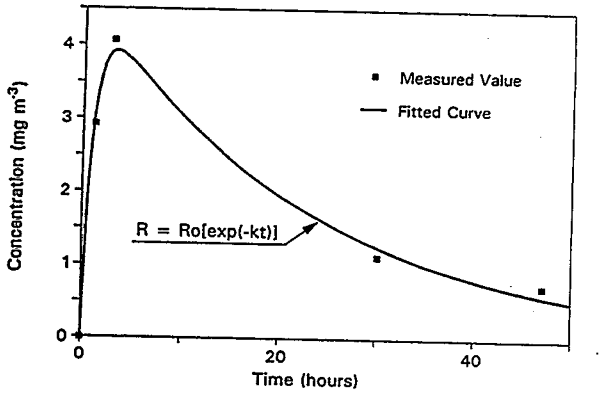


Figure 2. Perc emissions from drycleaned polyester/rayon (modeling of small chamber data).

We looked at a number of different fabrics initially—fundamentally for screening studies—and selected three specific fabrics: polyester-wool blend, 100 percent wool, and a polyester-rayon blend (Table 2). These same fabrics were used as the primary material in clothing that we had drycleaned and then placed in the test house. The studies in the test chambers, however, were done with bolt material that we had drycleaned.

Table 2. Small chamber test: Perc emission rates.

Fabric	ACH (/hr)	Ro (mg/m2-hr)	k (/hr)	Ro/k (mg/m2)	t(1/2) (hr)
Polyester/	0.25	1.50	0.028	54	27
Wool (Suit)	1.00	2.40	0.045	54	16
	2.00	0.80	0.028	29	25
100% Wool	0.25	0.93	0.041	23	20
(Skirt)	1.00	1.20	0.028	43	26
	2.00	0.80	0.052	15	19
Polyester/	0.25	0.56	0.022	26	34
Rayon (Blouse)	1.00	1.10	0.038	28	19
	2.00	0.47	0.027	17	25

One of the rates we studied concerned the effect of air exchange—air changes per hour. (Although we also looked at the effect of temperature, the data is not provided here.) The study found the decay rate for the three different fabrics to be slightly different, and found some difference in the air exchange rate of individual fabrics. We also were trying to determine whether there is a consistent change in the decay rate with the air exchange rate that would indicate evaporative mass transfer. While the data do not indicate that relationship, they do show that the evaporative mass transfer did occur, hopefully back at the drycleaners. The data show a desorption, which is why the rate is so slow. We also looked for the total mass of perc in the material. The data generally show that the polyester-wool blend holds more perc than the 100 percent wool or the polyester-rayon. Additionally, we looked for what are called *half-lives*. This is the amount of time required for the emission rate to divide itself by two, or to go down by 50 percent. This is measured in hours, so our findings are in the order of days. Thus, hanging clothes out to air is not particularly practical since it takes a number of days for the perc level to drop.

Our indoor air quality test house is a conventional three-bedroom house (Figure 3). For our study, we hung a three-piece suit, a skirt, and two blouses in a closet of the test house after all the garments were drycleaned. We measured the concentration of perc in (1) the closet, (2) the corner bedroom, and (3) the den (the living room and den are connected). The house was closed up during the test period, but the furnace and air-conditioning systems were left operating. We ran the experiment at 20°C, pretty cool, but not unusually so. The results are presented in mg/m³. Figure 4 shows levels of perc in the closet over a

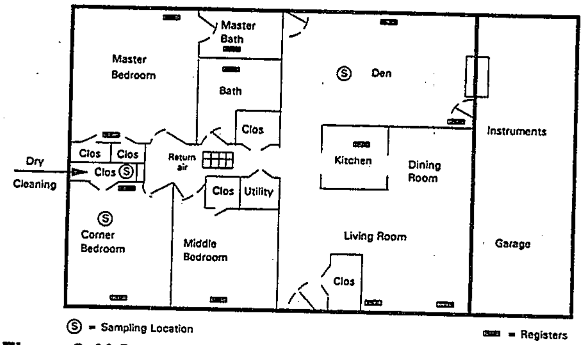


Figure 3. IAQ test house: Drycleaning experiment.

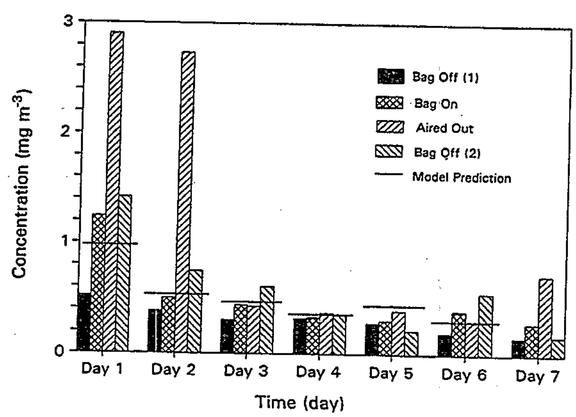


Figure 4. Perc concentrations in test house closet.

*1 ppm = 6.89 mg/m³ or 6,890 µg/m³

seven-day period. We ran each test for a week under a variety of conditions.

Let me explain that we had a condition called *bag off*, which means we took the plastic bag off the clothes before we hung them in the closet. We had a condition called *bag on*, where we left the plastic bag on the clothes. We had a condition called *aired out*, where we aired the clothes outside for a period of six hours, and a condition called *bag off two*, which was a replicate of this first condition. Figure 4 shows our predictions made with our indoor air quality model, based on the emission factors we observed in our small test chambers.

That data would seem to indicate that airing clothes out actually increases the level of perc. Actually, we observed a normal rate of decay. We found a fairly poor correlation, however, between these individual experiments. In my opinion, this was simply because when we took the clothes to the drycleaner and brought them back, they had different amounts of perc. This was probably the greatest variable in the study. In terms of control, we took the clothes to the same drycleaner—a local drycleaner near our laboratory—and asked that they be handled in a standard way, including pressing.

We found levels nearly as high as 3 mg/m^3, which for an indoor pollutant is a fairly high level, especially for organics. But that was in the closet. Figure 5 shows concentrations of perc in the adjoining bedroom that were about an order of magnitude lower than concentrations in the closet. The maximum concentration was around 2 mg/m^3, dropping below .05 mg/m^{3}after a reasonable period. In the den (Figure 6), the values were even lower. The maximum concentration was less than, than .1 mg/m^3, and the average values after a few days were around .02, or 20 μg/m^3.

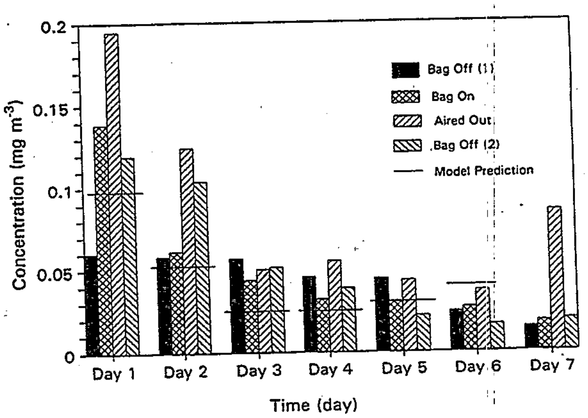


Figure 5. Perc concentrations in test house bedroom.

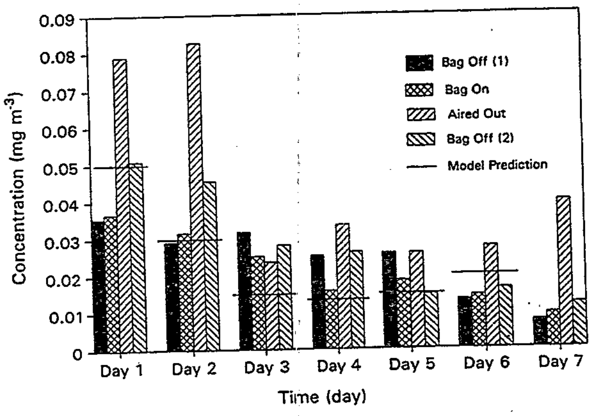


Figure 6. Perc concentrations in test house den.

So, we found that when you bring drycleaned clothes into your home, you get elevated levels of perc in the air. Levels are highest where you keep the clothes—not surprisingly—next highest in the adjacent room, and the rest of the house also has some measurable concentrations. Thus, anybody in *this* house is going to have some level of exposure to perc from the drycleaned clothing. When the clothes in our study were hung outside for a time, a perc decay rate for most of the fabrics was on the order of .02 to .03. This indicated that airing out drycleaned clothes—in this case for six hours—will only reduce the amount of perc in the drycleaned material by about 20 percent (Figure 7). So, it's not a very effective way of reducing perc concentrations.

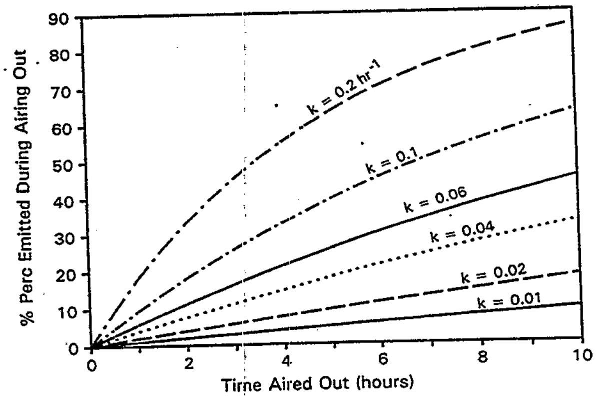


Figure 7. Effect on perc concentrations in garments after airing out.

Industry Research on Drycleaning Residual Reduction

Thomas A. Robinson, Ph.D.
Halogenated Solvents Industry Alliance

Dr. Robinson is manager of regulatory affairs for Vulcan Chemicals of Birmingham, Alabama, and chairperson of the Regulatory and Legislative Affairs Committee of the Halogenated Solvents Industry Alliance. His 28 years of industry experience include working as an analytical research chemist in environmental and worker protection areas and serving on numerous industry/trade association committees. He holds a doctorate in chemistry from Loyola University, Chicago.

Introduction

For the past few years, representatives of the drycleaning and solvent-producing industries have been involved in discussions with EPA's Office of Toxic Substances (now the Office of Pollution Prevention and Toxics) staff about ways to minimize perchloroethylene (perc) residuals in drycleaned clothes. One of the parameters considered is whether there are changes that could be made in the drycleaning process that would significantly affect the level of residual perc.

The two steps in the drycleaning process that would appear to have the greatest impact on perc residual levels are drying and finishing. Since drying time is usually controlled automatically, especially on newer dry-to-dry machines, it was decided that the finishing step would be the more appropriate area to examine.

A small study[1] was designed to look at the differences in perc emissions from drycleaned clothing before finishing and after three different finishing regimens. For various technical reasons, it was decided that it was more appropriate to measure perc emissions in a test house as opposed to actual perc residual levels in fabrics.

Methods

Five identical men's wool-blend (75 percent wool/25 percent polyester) suit coats were selected for the study. These garments are not representative of a "typical" drycleaning order, but were chosen to ensure that measurable differences in emissions likely to be caused by differences in finishing are analytically identifiable.

The suits were cleansed in a dry-to-dry, refrigerated, no-vent machine each Monday morning for four weeks as part of a 28-pound wool and wool-blend dummy load. The manufacturer's recommended cleaning cycle for these types of garments was selected. Before the first cleaning started, a technical representative verified the machine's specifications. Each suit was finished on a steam-air finisher operated at a steam pressure of 70-80 psi and maximum air pressure. After finishing, the clothes were transported to the test house, hung in the front bedroom closet with the door open, and air samples were taken about five feet from the suits every four hours for five days. The four different finishing regimens are shown in Figure 1.

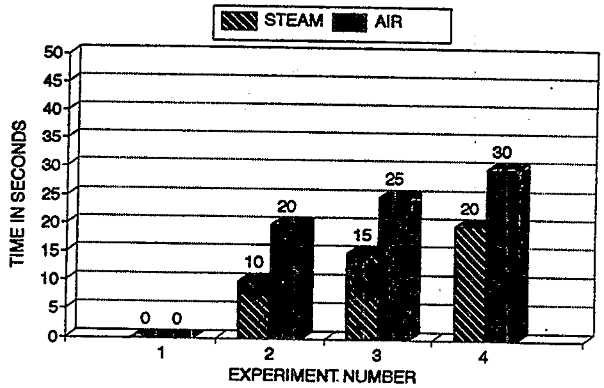


Figure 1. Steam and air finishing times.

[1] The study was sponsored by the International Fabricare Institute, the Halogenated Solvents Industry Alliance, the Neighborhood Cleaners Association, and the Textile Care & Applied Trades Association. It was performed by Geomet Technologies, Inc., Germantown, Maryland. N.L. Nagda, Ph.D., was the principal investigator.

Results

A moving average (i.e., average of current sample, two preceding, and two subsequent samples) was used to determine the 16-hour period with the highest concentrations within each testing week. The highest average (peak exposure) for each five-day test was statistically contrasted with that of the control (i.e., zero seconds of steam or air, using the t-test). The results are in Figure 2.

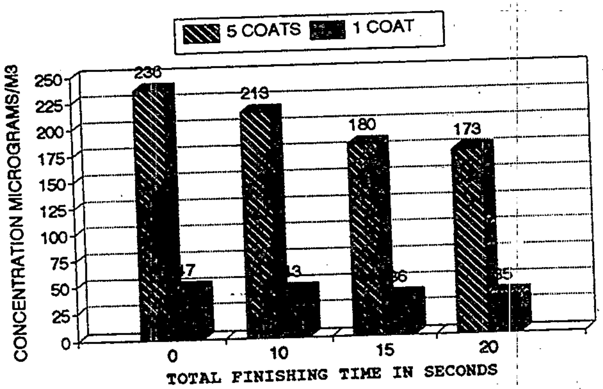


Figure 2. Effect of total finishing time on maximum perc concentration.

The hatched bars represent the perc concentration associated with each finishing regimen, while the solid bars represent the perc that might be expected from a single suit coat. The perc emissions resulting from the last two finishing regimens are significantly lower than the control. It should be noted that the level from the second finishing regimen (steam/air = 10/20 seconds) is probably higher than would be expected due to an error in the air changes/hour: 0.1 for second regiment versus 0.3 for the others. This error is most obvious when the data is plotted on a curve (Figure 3).

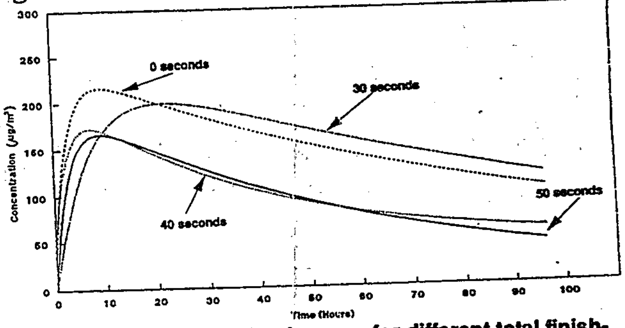


Figure 3. Comparison of fitted curves for different total finishing times.

The finishing process applied to the clothes after drycleaning reduced the amount of perc in the bedroom of the test house. The magnitude of reduction for the longest finishing regimen was on the order of 25 percent. A clear correlation between length of finishing time and emissions does not look promising. A significantly longer finishing time would appear to be required to obtain any further significant reduction in perc residuals. This solution would not be acceptable to the average drycleaner because it would not be cost-effective.

Drycleaning in Japan: Current Conditions and Regulations

Junji Kubota

All Japan Laundry and Drycleaning Association

Mr. Kubota is a deputy manager at the All Japan Laundry and Drycleaning Association, where he is responsible for coordinating interactions between the Japanese government and the drycleaning and laundry industry. He serves on the Ministry of Health and Welfare's Drycleaning Solvent Committee and holds a law degree from Meiji Gakuin University.

In Japan, four types of drycleaning solvents are used. Table 1 shows the number of drycleaning machines in use in Japan during 1989 by type of solvent used and the number of drycleaning establishments. As shown in this table, machines and establishments that use petroleum-based solvents make up 70 percent of the total, those that use perchloroethylene (perc) account for 20 percent, and those that use CFC-113 or 1,1,1 trichloroethane account for 5 percent. The large number of petroleum-based-solvent machines is particularly noteworthy.

Table 2 shows the estimated amount of drycleaning solvents used in Japan during the same year.

Table 3 provides a breakdown of garments drycleaned in Japan by type of solvent. As shown, the amounts of garments cleaned with petroleum-based solvents and perc were virtually the same. Table 4 shows the household market for clothing cleaning services from 1987 through 1991. It indicates that demand is increasing year by year.

Table 1. Drycleaning machines and establishments in Japan by type of solvent (1989).

	Number of facilities using drycleaning machines	Number of unit of drycleaning machines in use
Petroleum solvent	33.700	35.500
Perchloroethylene	9.700	10.700
Metylchloroform	1.800	1.800
CFC-113	1.700	1.900
Total	46.900	49.900

Table 2. Estimated deliveries of drycleaning solvent (1989).

	Estimated deliveries of drycleaning solvent (ton)
Petroleum solvent	7.700
Perchloroethylene	18.000
Metylchloroform	2.700
CFC-113	4.100

Table 3. Percent of garments cleaned by type of solvent.

	Component ratio of garment according to solvent (%)
Petroleum solvent	40.2
Perchloroethylene	40.2
Metylchloroform	6.3
CFC-113	13.3

Table 4. Household market for clothing cleaning services in Japan (1987-1991).

Fiscal year	1987	1988	1989	1990	1991
Expense per household(Yen)	15,729	16,158	16,726	17,236	17,240
No. of household(×1,000)	39,536	40,025	40,561	41,156	41,797
Sales (Million Yen)	621,800	646,700	678,400	709,400	720,600

The distinctive features of Japan's clothing cleaning industry are:

- Almost all clothing cleaning establishments provide both drycleaning and conventional laundry services.
- Virtually all petroleum-based-solvent machines are of the transfer type. However, in all establishments where the other three solvents are used, equipment is of the dry-to-dry type.
- Relative to the size of the population, the number of clothing cleaning establishments is large. The number of pickup stations that do not actually perform cleaning is also large, as is the number of small, "mom-and-pop" type operations.
- Coin-operated drycleaning machines have not been widely adopted in Japan.

In Japan, the cleaning industry falls under the administrative jurisdiction of the Ministry of Health and Welfare (MHW) and is regulated under the Cleaning Business Law, which covers not only drycleaning but also conventional laundry services. Notification concerning building construction, equipment, and other matters is required to operate a clothing cleaning business, and facilities must be inspected in advance. In addition, the clothing cleaning establishment is responsible for formally securing certification as a Registered Cleaning Supervisor.

Regulation of Drycleaning Solvents

Petroleum-Based Solvents

Because of the flammability of petroleum-based solvents, building codes and fire regulations prohibit their use in residential and commercial areas. In addition, cleaning establishments must apply for approval to construct storage facilities of 1,000 liters (260 gallons) or more of solvents, and must give notice of the construction of facilities for storing 200 to 1,000 liters (52 to 260 gallons).

No national regulations are applied to emissions into the atmosphere, but in some areas operators are required by local ordinance to install exhaust gas recovery equipment to suppress photochemical smog. Where the workplace environment is concerned, however, operators must post precautions to be observed when handling these cleaning fluids and must designate a person responsible for work involving organic solvents, among other measures.

Perchloroethylene (Perc)

The problem of environmental pollution from perc in Japan began with ground water in 1981, when perc was detected in the underground water sources for several cities. In addition, perc was listed as a harmful substance by the Water Pollution Control Law and Sewerage Law, and an effluent standard of 0.1 mg/l and under for perc was implemented.

In March 1989, perc was designated a Class 2 Specified Chemical Substance on the basis of statutes regulating the inspection and production of chemical substances, resulting in restrictions on both production and imports. In line with this designation, the MHW and the Ministry of International Trade and Industry (MITI) announced a *Guideline on Technical Measures for Cleaners on Prevention of Environmental Pollution by Perchloroethylene*, which was intended to eliminate perc pollution from drycleaning operations. This guideline recommended methods of storing solvents, and of using, maintaining, and inspecting drycleaning machines, effluent treatment equipment, and facilities. Methods of using exhaust air recovery equipment to control emissions and approaches for handling sludge were also described.

Where sludge containing perc is concerned, laws governing the treatment and cleaning of wastes require that annual reports detail arrangements for persons responsible for the treatment of industrial wastes, notification regarding equipment and facilities, and information on the status of treatment operations. A manifest system is used to track the treatment process when waste treatment is contracted out to third parties. Moreover, following the revision of laws last year, there is a strong possibility that perc will be designated as a Specially Controlled Industrial Waste.

In the organic solvent protection regulations included in the Labor Safety and Health Law, the control concentration for the workplace environment in cleaning plants is stipulated as 50 ppm or less.

For further guidance, the All Japan Laundry and Drycleaning Association has prepared a handbook describing appropriate measures the industry should take to prevent environmental pollution. Perc-using cleaning operators in Japan are making active use of this publication.

CFC-113 and 1,1,1-Trichloroethane

Although a decision has already been made to totally eliminate the use of CFC-113 and 1,1,1-trichloroethane in the near future, a policy for rationalizing the use of these substances has been announced, and strenuous efforts are being made to minimize emissions from machines still in service that use these solvents.

Measures to Reduce Residual Drycleaning Solvents in Garments

Although restrictive measures have been implemented in all areas based on laws concerning direct environmental pollution from cleaning plants and equipment, the indirect effect of trace amounts of drycleaning solvents remaining in garments after they have been returned to the customer continues to be a problem.

Petroleum-Based Solvents

A number of cases of skin problems caused by residual solvents in garments cleaned with petroleum-based cleaning fluids has been reported. Also, complaints made to consumer centers regarding incomplete drying are increasing. To prevent this problem, it is essential that garments be dried completely before being returned to the owner. Figure 1 shows a device that uses a semiconductor sensor to measure whether a garment is actually dry. When the Dry Checker is applied to the garment, the sensor detects

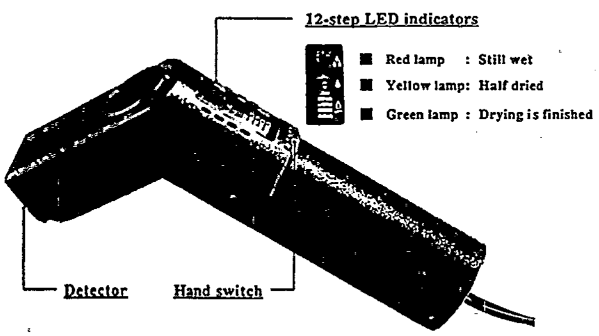


Figure 1. Cactus Dry Checker: Device to measure drycleaning solvent.

the vapor of residual solvent and measures the concentration (Table 5). If the residual amount is 60 ppm or less (green lamp), no danger of skin problems is posed. With government support, the industry is working to ensure general use of this device.

Figure 2, for example, shows the transition of residual solvents when drying a windbreaker with

Table 5. Relationship among the LED color, solvent vapor concentration, and degree of dryness.

Color and position of the indicator lamp		Vapor concentration of n-Undecane in ppm	Measurement criterion	Reference
Green	1	14 or lower	Drying finished	No odor
	2	14 – 25		Very little odor
	3	25 – 40		(very little solvent remains)
	4	40 – 60		
Yellow	1	60 – 100	Half dried	Odor (some solvent still remains, which may cause odor)
	2	100 – 140		
	3	140 – 200		
	4	200 – 300		
Red	1	300 – 400	Still wet	Strong odor (a considerable amount of solvent still remains, which may cause skin inflammation)
	2	400 – 600		
	3	600 – 1,300		
	4	1,300 or over		

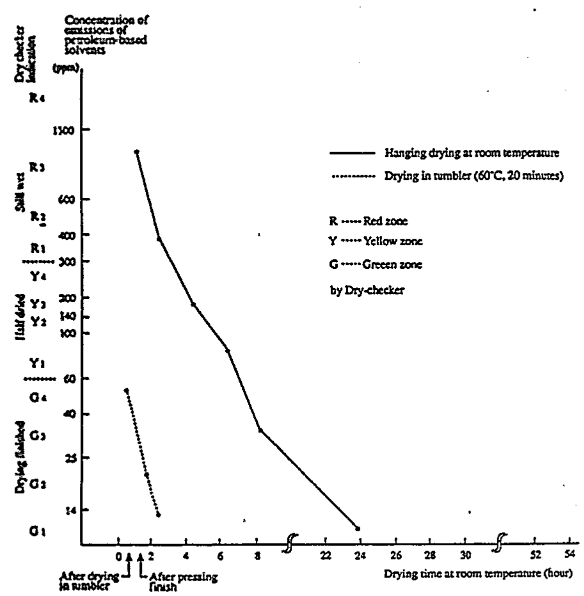


Figure 2. Effect of drying time on emissions of petroleum-based solvents from a windbreaker with cow leather (left shoulder).

cowhide parts. Care must be taken in natural drying since the length of time required varies with temperature, humidity, and other conditions, and the speed of drying varies for different parts of the garment. Fabricated and natural leathers are particularly difficult to dry, and shoulder pads and linings tend to dry slower than other parts.

Perchloroethylene

In recent years, indirect pollution of the immediate living environment in Japan by residual chemicals in garments has attracted attention. Reports indicate that some atmospheric pollution in households is attributable to garments that have been drycleaned with perc. For this reason, the industry is conducting research into ways of reducing the residual concentration of perc in drycleaned clothing.

Results obtained from experiments conducted to date include the following. Table 6 shows the amount of perc remaining in various fabrics immediately after they were taken from the drycleaning machine. Residual amounts ranged from 0.14 to 1.58 mg/g of fabric, with acetate showing a particularly high concentration. The results do not seem to be related to the air-permeability of the fabric.

Table 6. Relationship between fibers and residual amounts of perc.

Fibers					Residual amount of perc (mg/g)
Type		Texture	Mass (g/m^2)	Air-permeability ($cm^3/cm^2/s$)	
Wool	100%	Twill weave	273	13.4	0.427
Wool Nylon	93% 7%	Twill weave	365	36.3	0.119
Polyester	100%	Circular knitting	435	185.0	0.139
Cotton	100%	Knitted	154	150.5	0.202
Acetate fiber	100%	Plain weave	63	37.5	1.576
Polyester	100%	Twill weave	79	27.3	0.515

Another study considered the effect of finishing processes on reductions in the residual amount of perc in garments after they were removed from the drycleaning machine. Figure 3 indicates that finishing does reduce the perc content in wool. It was also found that tumbler drying with heated fresh air followed by steam-box finishing had approximately the same degree of effectiveness in reducing the residual perc content. Further research is planned.

A simple measurement device capable of objectively determining the residual amount of perc—like the Dry Checker for use on petroleum-based solvents—is needed. The industry has tested a simple device that uses a semiconductor sensor, but the measurement level for residual concentrations is considerably lower with perc than with petroleum-based solvents. As a result, perc concentrations cannot be adequately detected with the current technology. It is

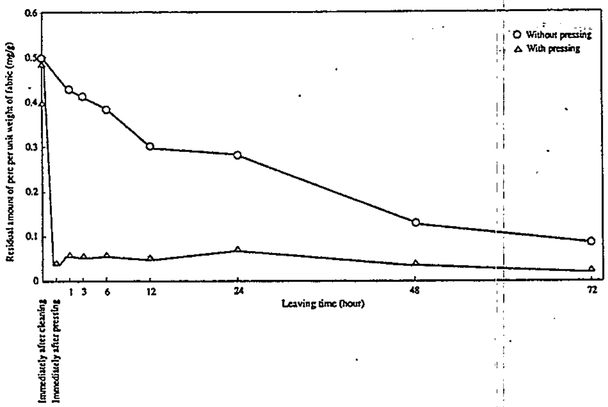


Figure 3. Residual perc in wool fabric with and without finish pressing.

expected that structural improvements will lead to the development of a measurement device capable of solving this problem.

It should be noted that the tests discussed above were conducted with duct-system drycleaning machines. With the recently introduced nonducted, closed-circuit-system machines, however, the concentration in the cylinder is higher, which may lead to higher residual concentrations in garments at completion of drycleaning. Study of this drycleaning system will be necessary in the future.

Roundtable Discussion Summary: Residual Reduction

Discussion about residual reduction began with an observation by Hans-Dietrich Weigmann of the Textile Research Institute concerning the results presented by the EPA's Bruce Tichenor. Dr. Weigmann noted that in the concentration time profiles from the EPA indoor air study, the concentrations in the test closet were higher for samples that had been aired out prior to hanging in the closet. This appeared to be an anomaly. Dr. Weigmann hypothesized that if the samples were hung in areas of higher humidity that this could increase the rate of desorption occurring in the fabric. Dr. Tichenor agreed that this was an interesting observation and that it might explain the results that were obtained.

Judy Schreiber of New York State Department of Health inquired about the guidelines for air and water concentrations of perc in Japan, and whether problems of perc in food had been looked at. Junji Kubota of the All Japan Laundry and Drycleaning Association responded that the regulatory limits for indoor air for workers are 50 ppm and 0.1 milligrams per liter (μg/l) for water. To date, neither the authorities nor the drycleaning industry has looked at concentrations in food.

Dr. Schreiber then asked Dr. Tichenor if the EPA had looked at the absorption and desorption of building materials such as wallboard. Dr. Tichenor responded that other EPA studies had looked at the so-called sink effect and found that most organics are absorbed by materials such as wallboard, carpet, ceiling tile, and upholstery, and that it can take months for these materials to release all of the perchloroethylene they may have absorbed. Dr. Schreiber indicated that this is what had been found in their studies in New York. Perc levels in apartments took a long time to fall after drycleaning operations in the buildings had been shut down.

Tom Robinson of the Halogenated Solvents Industry Association reopened the debate from the previous panel on whether increased airflow in the drying stage is sufficient to reduce residuals in clothing. Dr. Weigmann responded that the rate-determining step seems to be the diffusion of perc to the fiber surface, not desorption from the surface. If this is true, then boosting airflow will not help reduce residuals. Manfred Wentz of R.R. Street added the opinion that, even if increased airflow could reduce residuals, the length of time necessary to aerate the clothing would not be practical.

Scott Lutz of the Bay Area Air Quality Management District suggested that the key to consistently low residuals is automation of the drying cycle with inline continuous monitoring of air concentration such as is required in Germany.

Jack Lauber of the New York Department of Environmental Conservation wondered about the effectiveness of the azeotropic vapor condensation systems, which humidify the air passing over the clothes to increase the amount of perc given up. Dr. Weigmann agreed that raising the humidity will increase the desorption rates of cellulosic fibers such as cotton, wool, and, to a lesser extent, silk and nylon (but not polyester). Dr. Wentz cautioned, however, that by adding moisture and combining it with mechanical action there is an increased possibility of fiber damage and shrinkage, which defeats the whole purpose of drycleaning.

Elizabeth Bourque of the Massachusetts Department of Health admitted some ignorance concerning alternative solvents used for drycleaning and asked for information on their advantages and disadvantages. In particular, she wondered why in Japan some 70 percent of drycleaning is done with petroleum solvents, as shown in Mr. Kubota's slides. Shozo Tamura of Nippon Mining Company explained that in Japan the industry had historically used petroleum solvents but that, due to the fire hazards, it had gradually switched to perc. Some 70 percent of machines in Japan operate with petroleum solvent; however, over 50 percent of clothes are cleaned using perc. Dr. Wentz explained that petroleum solvent had been and still is used in the United States, but that it has been mostly phased out, for three reasons: (1) the fire hazard, (2) the photochemical reactivity, and (3) the presence of aromatics that are carcinogenic. Bill Fisher of the International Fabricare Institute indicated that approximately 15 percent of drycleaners in United States still use petroleum solvents but that their use is increasingly rare. In most urban areas it would not be possible to establish a new petroleum-based operation because of the stringent fire codes. Mr. Fisher also pointed out that solvent substitution is not just a matter of draining out the perc from the machine and replacing it with an alternative. Since perc substitutes cannot be used with the existing equipment, the operator would be looking at complete equipment replacement as well.

Ken Adamson of the Launderers and Drycleaners Institute of Ontario provided a final comment on the operator's perspective concerning replacement of equipment. He suggested that the operators need to know that the equipment they purchase will be sufficient to satisfy regulatory requirements for the next 10 to 20 years if there is to be any chance for payback. No operator would replace his equipment if it appeared that the regulations would be changing again in 4 or 5 years.

FOOD AND RESIDENT EXPOSURE REDUCTION

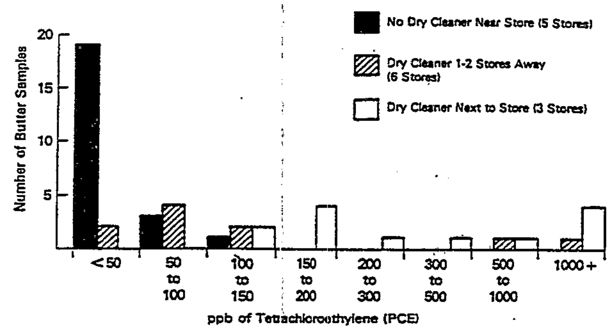
Perchloroethylene Levels in Foods Obtained near Drycleaning Establishments

Gregory W. Diachenko, Ph.D.
Center for Food Safety and Applied Nutrition
U.S. Food and Drug Administration

Dr. Diachenko is a branch chief in the FDA's Division of Food Chemistry and Technology with 20 years of experience studying chemical contaminants in food. He has been the lead FDA scientist on numerous food contamination incident investigations, including several dealing with volatile halocarbons such as perchloroethylene. His research on chemical contaminants and additives in food has been reported in more than 25 scientific publications and numerous presentations. Dr. Diachenko holds a Ph.D. in chemistry, with a specialization in environmental and analytical chemistry, from the University of Maryland.

Findings of low levels (generally <100 µg/kg) of volatile halocarbons (VHCs) such as chloroform, 1,1,1-trichloroethane, trichloroethylene, and perchloroethylene (PCE) in foods have been reported by several investigators (Uhler and Diachenko, 1987; Daft, 1988; Heikes, 1987; Entz et al., 1982). The data generated by Heikes (1987) on 231 different foods from the U.S. Food and Drug Administration's (FDA) Total Diet Survey indicate that background levels of PCE in foods are generally less than 50 µg/kg (Table 1). In 1988, Entz and Diachenko reported finding PCE in four margarines at levels (500 to 4,000 µg/kg) significantly above the usual background levels (Table 2). Those margarines had been obtained from a food store located immediately next to a drycleaning establishment. A follow-up investigation was conducted by Miller and Uhler (1988) to determine the frequency of occurrence and levels of PCE that may be present in fatty foods purchased from stores located both near and distant from drycleaners.

Miller and Uhler (1988) examined 46 butters collected from 14 retail outlets in the Washington, DC, area to determine the incidence and levels of PCE. Butter was chosen as a model food because it is a uniform product with very high fat content that would be expected to act as a good absorber of PCE. Butters were purchased from food stores located next to or at various distances from drycleaners as well as stores located where there were no drycleaners in the vicinity. As suspected from the previous work by Entz and Diachenko (1988), butters obtained from stores located near drycleaning establishments contained elevated levels of PCE (Figure 1). The butters collected from stores with no drycleaners nearby generally contained less than 50 ppb of PCE. However, many of



Source: Miller and Uhler, 1988.

Figure 1. Perchloroethylene (PCE) concentrations in butter from stores located at various distances from drycleaning establishments.

Table 2. Findings of volatile halocarbons (VHCs) in margarines (1980-1982).

Residue Range[a] (ppb)	No. of samples containing residue		
	MC	TCE	PCE
< 5000-500			4[b]
< 500-100	4	1	1
< 100-50	6	–	1
< 50	21	9	9
Trace[c]	10	7	18
Not detected	11	35	23

Note: A total of 56 products were purchased from food stores in the Washington, DC, area.
[a] No attempt was made to account for variation in residue concentration within a stick. This value represents the level present in a pat taken from the middle third of a stick.
[b] All four products were from a store located next to a drycleaner.
[c] Trace defined as: < 5 ppb of MC; < 10 ppb of TCE; < 4 ppb PCE. Detection limits are approximately 1/3 the trace levels.

Source: Entz et al., 1988.

Table 1. Ten residues determined from 231 food samples examined.

Item	Fat content %	Grain based (gb)	Amount determined, ng/g									
			CS_2	CCl_4	CP	EDB	EDC	$CHCl_3$	CH_2Cl_2	CH_3CCl_3	PCE	TCE
Cereals												
Cornflakes	non	gb	–	–	–	–	–	–	–	–	–	–
Fruit flavored cereal	non	gb	–	–	–	–	–	–	–	–	3	–
Shredded wheat cereal	non	gb	–	–	–	–	–	100	–	4	17	–
Raisin bran cereal	non	gb	–	–	–	–	–	68	1440	6	14	–
Krisped rice cereal	non	gb	–	–	–	–	–	–	4400	–	108	–
Granola, plain	non	gb	–	2	–	–	–	48	–	22	40	–
Oat ring cereal	non	gb	–	–	–	–	–	52	1760	6	14	–
Rolled oats, cooked	non	gb	–	–	–	–	–	–	–	35	2	–
Farina, cooked	non	gb	–	–	–	–	–	–	920	8	2	–
Corn grits, cooked	non	gb	–	–	–	–	–	–	–	3	1	–
Oils/dressings												
Salad dressing, Italian	72.4		–	–	–	–	–	–	–	–	–	–
Vegetable oil, corn	100.0		–	–	–	–	–	240	–	–	21	–
Mayonnaise, bottled	80.0		–	–	–	–	–	–	–	–	–	–
Vegetables												
Pinto beans, boiled	non		–	–	–	–	–	–	–	–	–	–
Pork & beans, canned	non		–	–	–	–	–	–	–	–	2	–
Cowpeas, boiled	non		–	–	–	–	–	–	–	–	–	–
Lima beans, mature	non		–	–	–	–	–	–	–	–	–	–
Lima beans, immature	non		–	–	–	–	–	–	–	–	–	–
Navy beans, boiled	non		–	–	–	–	–	–	–	–	–	–
Red beans, boiled	non		–	–	–	–	–	–	–	–	–	–
Peas, green, canned	non		–	–	–	–	–	–	760	1	–	–
Peas, green, boiled	non		–	–	–	–	–	–	1200	2	2	–
Rice, white, cooked	non	gb	–	–	–	–	–	–	–	–	–	–
Corn, boiled	non	gb	–	–	–	–	–	–	–	2	3	–
Corn, canned	non	gb	–	–	–	–	–	–	280	–	–	–
Corn, cream style	non	gb	–	–	–	–	–	–	–	–	–	–
Spinach, canned	non		–	–	–	–	–	25	–	–	–	–
Spinach, boiled	non		–	–	–	–	–	100	–	–	–	–
Collards, boiled	non		–	–	–	–	–	44	–	–	–	–
Lettuce, raw	non		–	–	–	–	–	30	–	–	–	–
Cabbage, boiled	non		–	–	–	–	–	72	–	–	–	–
Coleslaw, with dressing	15.7		–	–	–	–	–	9	–	–	–	–
Sauerkraut, canned	non		–	–	–	–	–	–	–	–	–	–
Broccoli, boiled	non		–	–	–	–	–	–	–	–	–	–
Celery, raw	non		–	–	–	–	–	14	–	–	–	–
Asparagus, boiled	non		–	–	–	–	–	–	–	–	–	–
Cauliflower, boiled	non		–	–	–	–	–	–	–	–	–	–
Tomatoes, raw	non		–	–	–	–	–	10	–	–	–	–
Tomato juice	non		–	–	–	–	–	–	–	–	–	–
Tomato sauce	non		–	–	–	–	–	–	–	–	–	–
Tomatoes, canned	non		–	–	–	–	–	–	–	–	–	–
Green beans, boiled	non		–	–	–	–	–	28	–	–	–	–
Green beans, canned	non		–	–	–	–	–	–	–	–	–	–
Cucumber, raw	non		–	–	–	–	–	–	–	–	–	–
Squash, summer, boiled	non		–	–	–	–	–	–	–	–	–	–
Sweet pepper, green, raw	non		–	–	–	–	–	31	–	–	–	–
Squash, winter, boiled	non		–	–	–	–	–	–	–	–	–	–
Carrots, raw	non		–	–	–	–	–	–	–	–	1	–
Onions, raw	non		304	–	–	–	–	–	–	–	–	–
Mixed vegetables, canned	non		–	–	–	–	–	–	–	–	2	–
Mushrooms, canned	non		–	–	–	–	–	12	–	–	–	–
Beets, canned	non		–	–	–	–	–	–	–	–	–	–
Radish, raw	non		440	–	–	–	–	24	–	–	–	–
Onion rings, cooked	12.7	gb	–	–	–	–	–	52	–	9	5	–
French fries, cooked	6.0		–	–	–	–	–	20	–	2	9	–
Mashed potatoes	5.0		–	–	–	–	–	–	–	6	–	–
Boiled potatoes	non		–	–	–	–	–	22	–	–	–	–
Baked potatoes	non		–	–	–	–	–	–	–	–	–	–
Scalloped potatoes	4.0		–	–	–	–	–	–	–	–	–	–
Sweet potatoes, baked	non		–	–	–	–	–	11	–	–	–	–
Sweet potatoes, candied	non		–	–	–	–	–	8	–	3	–	–
Cream of potato soup	non		–	–	–	–	–	–	–	2	–	–
Vegetable beef soup	non		–	–	–	–	–	–	–	–	–	–
Pickles, dill	non		–	–	–	–	–	–	–	–	–	–
Catsup	non		–	–	–	–	–	–	–	2	–	–
Strawberry gelatin	non		–	–	–	–	–	–	–	–	–	–

Table 1. Ten residues determined from 231 food samples examined (continued).

			Amount determined, ng/g									
Item	Fat content %	Grain based (gb)	CS_2	CCl_4	CP	EDB	EDC	$CHCl_3$	CH_2Cl_2	CH_3CCl_3	PCE	TCE
Baked goods												
Popcorn, popped	29.5	gb	—	—	—	—	—	44	—	—	16	—
White bread, enriched	3.5	gb	—	—	—	—	—	—	—	—	3	—
White rolls, soft	5.2	gb	—	—	—	—	—	52	—	—	14	—
Cornbread, southern	9.4	gb	—	—	—	—	—	96	—	3	6	—
Biscuits, baking powder	7.4	gb	—	—	—	—	—	56	400	2	4	—
Whole wheat bread	2.3	gb	—	—	—	—	—	16	—	—	12	—
Flour tortilla	4.2	gb	—	—	—	—	—	26	—	—	6	—
Rye bread	2.0	gb	—	—	—	—	—	—	—	—	7	—
Muffins, blueberry	8.6	gb	—	—	—	—	—	56	408	11	48	—
Saltine crackers	7.7	gb	—	—	—	—	—	128	720	7	8	—
Corn chips	28.9	gb	—	2	12	—	—	136	1040	9	30	—
Pancakes	6.7	gb	—	—	—	—	—	132	760	3	6	—
Noodles, egg, cooked	non	gb	—	—	—	—	—	—	—	—	—	—
Macaroni, cooked	non	gb	—	—	—	—	—	—	—	—	3	—
Potato chips	28.4		—	—	—	—	—	76	760	8	16	—
Macaroni and cheese	5.4	gb	—	—	—	—	—	56	—	2	4	—
Chocolate cake/icing	16.3	gb	—	—	—	—	—	—	104	40	18	—
Yellow cake	9.7	gb	—	—	—	—	—	40	84	40	6	—
Coffeecake, frozen	12.6	gb	—	—	—	—	—	—	72	14	6	—
Donuts, cake, plain	21.7	gb	—	—	—	—	—	48	—	17	20	—
Sweet roll, Danish	13.7	gb	—	—	—	—	—	—	320	29	12	—
Cookies, chocolate chip	22.5	gb	—	—	—	—	—	60	136	8	8	—
Cookies, sandwich	19.8	gb	—	—	—	—	—	—	—	28	12	—
Apple pie, frozen	10.5	gb	—	—	—	—	—	—	—	14	16	—
Pumpkin pie, frozen	7.9	gb	—	—	—	—	—	—	—	—	6	—
Nuts/nut products												
Peanut butter, creamy	57.1		—	—	—	—	—	32	—	10	3	—
Peanuts, dry roasted	43.5		—	—	—	—	—	72	—	24	—	—
Pecans	63.1		—	—	—	—	—	40	—	228	120	—
Dairy products												
Whole milk	3.7		—	—	—	—	—	8	228	1	2	—
Lowfat milk	2.0		—	—	—	—	—	—	—	—	2	—
Chocolate milk	2.6		—	—	—	—	—	84	—	5	17	—
Skim milk	non		—	—	—	—	—	—	—	—	—	—
Buttermilk	non		—	—	—	—	—	10	—	—	6	—
Yogurt, plain	1.4		—	—	—	—	—	—	—	—	2	—
Milkshake, chocolate	3.4		—	—	—	—	—	14	—	152	—	94
Evaporated milk	7.5		—	—	—	—	—	9	—	—	—	—
Yogurt, strawberry	1.4		—	—	—	—	—	—	—	2	3	—
Cheese, processed	28.0		—	—	—	—	—	96	600	8	21	—
Cottage cheese	4.3		—	—	—	—	—	52	—	—	2	—
Cheese, cheddar	31.4		—	—	—	—	—	312	—	16	30	—
White sauce	12.5	gb	—	—	—	—	—	15	—	10	2	—
Margarine, stick	80.0		—	—	—	—	—	79	—	13	—	—
Butter, stick	80.0		—	—	—	—	—	130	—	18	15	—
Cream, half & half	9.0		—	—	—	—	—	124	—	4	2	—
Cream substitute	21.5		—	—	—	—	—	—	—	—	—	—
Ice cream, chocolate	13.6		—	—	—	—	—	104	—	4	6	—
Instant pudding, chocolate	3.0		—	—	—	—	—	14	—	1	—	—
Ice cream sandwich	9.5	gb	—	—	—	—	—	22	—	15	28	—
Ice milk, vanilla	3.4		—	—	—	—	—	64	—	520	2	—
Sugars, jams, candy												
Sugar, white	non		—	—	—	—	—	—	—	—	—	—
Syrup, cane	non		—	—	—	—	—	—	—	—	—	—
Jelly, grape	non		—	—	—	—	—	—	—	—	—	—
Honey	non		—	—	—	—	—	—	—	—	—	—
Candy, milk chocolate	28.6		—	—	—	—	—	48	—	15	20	—
Candy, caramel	8.1		—	—	—	—	—	—	—	—	—	—
Chocolate powder, sweet	2.6		—	—	—	—	—	—	—	—	—	—
Meats/meat dishes												
Beef, ground, fried	20.5		—	—	—	—	—	34	—	8	2	—
Beef, chuck roast	20.1		—	—	—	—	—	116	—	6	4	—
Beef, round steak, stewed	12.0		—	—	—	—	—	—	—	—	9	—
Beef, sirloin, cooked	16.8		—	—	—	—	—	68	—	10	9	—
Pork, ham, cured	10.5		—	—	—	—	—	68	—	5	1	—
Pork chop, cooked	18.6		—	—	—	—	—	44	—	76	3	—
Pork, sausage, cooked	37.6		—	—	—	—	—	—	—	7	19	—

Source: Heikes, 1987.

the butters from stores located near drycleaners had elevated levels of PCE ranging from 100 to 1,000 μg/kg. Generally, butters from stores located immediately next to drycleaners had higher PCE levels than those from stores that were one or two stores removed from drycleaning operations.

Similar elevated levels of PCE have been reported by German investigators (Vieths et al., 1988, 1987) in fatty foods collected from private apartments and grocery stores located near drycleaning establishments or in the same building. The reported PCE levels were highly variable, ranging from <2 to 41,850 μg/kg in foodstuffs from apartments and from 5 to 18,750 μg/kg in foodstuffs from grocery stores near drycleaning establishments (Tables 3 and 4). Vieths et al. (1988) demonstrated similar elevated PCE levels (90 to 29,700 μg/kg) in synthetic fat exposed to the air in these apartments for 14 days. He also noted that the sealed packaging of a commercial margarine offered no long-term protection against PCE contamination by partitioning from air. Reinhard et al. (1989) and other German investigators found that a significant enrichment of PCE occurs in butter and sweet cream with increasing storage time in apartments near drycleaning operations (Table 5). PCE concentrations greater than the German Federal Health Office's (BGA) allowable limit of 1.0 mg/kg for marketable foodstuffs were exceeded in butter from four of the five apartments after 7 days refrigerator storage.

The previously cited PCE findings, combined with the widespread use of PCE as a drycleaning fluid, suggest that aerial transport of the vapors from the drycleaning process can be a source of PCE in butter, margarine, and other foods stored in apartments or grocery stores located near drycleaning establishments.

Table 3. Tetrachloroethylene (TCE) in food from retailers in the immediate vicinity of drycleaning establishments.

Case 4. Supermarket next to a drycleaner

4.1 Samples taken 3/5/87 at 4:40 p.m.

Sample	TCE in μg/kg
Margarine	110
Herb butter	7

4.2 Samples taken 3/25/87 at 4:40 p.m.

Sample	TCE in μg/kg
Cheese spread	36
Butter	21
Flour	25
Cornstarch	36

Case 9. Drycleaning establishment

9.1 Samples taken 5/11/87 at 11:15 a.m.

Sample	TCE in μg/kg
Fruit ice[a]	2
Chocolate-coated ice cream	1,330
Chocolate & nut-coated ice cream	4,450
Ice cream confection	18,750

[a] "Water ice"

Source: Vieths et al., 1988.

Table 4. Tetrachloroethylene (TCE) levels in foodstuffs from test locations.

Apartment	Sample	TCE Level μg/kg	Storage
B	garlic butter	120	≥ 2 months
B	vegetable oil	15	several weeks
B	margarine 1	30	several weeks
B	oatmeal	< 2	several weeks
B	flour	< 2	several weeks
C	cocoa	1,340	several weeks
C	flour	860	several weeks
C	margarine 2	3,300	10 days
C	margarine 3	5,070	several weeks
C	margarine	41,850	several weeks

Source: Vieths et al., 1988.

Table 5. Concentrations of tetrachloroethylene (TCE) in indoor air and in fat-containing food after 1, 3, 5, and 7 days of storage in test locations in the vicinity of drycleaning establishments.

	Apartment 1			Apartment 2			Apartment 3		
Day	Indoor Air (μg/m³)	Butter (mg/kg)	Sweet Cream (mg/kg)	Indoor Air (μg/m³)	Butter (mg/kg)	Sweet Cream (mg/kg)	Indoor Air (μg/m³)	Butter (mg/kg)	Sweet Cream (mg/kg)
Outdoor	13.68			3.07			21.87		
0	891.56	0.0012	0.0068	482.86	0.0012	0.0068	37.86	0.0012	0.0068
1	1,790.80	0.307	0.010	1,647.88	0.107	0.030	378.54	0.078	0.001
3	649.32	0.548	0.035	1,358.07	0.441	0.068	532.86	0.087	0.007
5	1,447.58	0.794	0.062	555.55	0.576	0.069	17.14	0.153	0.015
7	2,296.46	1.67	0.117	723.68	1.431	0.073	40.66	0.175	0.025
	Apartment 4			Apartment 5			Control Apartment 6		
Outdoor	138.24			3.4			0.008		
0	1,049.04	0.0055	0.0016	771.86	0.0055	0.0016	0.083	0.0055	0.0016
1	19.46	0.027	0.002	238.91	0.033	0.011	1.76	0.005	0.001
3	2,066.54	0.203	0.004	44.16	0.235	0.016	0.91	0.018	0.008
5	170.65	0.677	0.045	820.16	1.097	0.018	6.37	0.031	0.014
7	484.91	1.491	0.054	1,401.87	1.651	0.027	1.48	0.094	0.015

Source: Reinhard et al., 1989.

References

Daft, J.L., 1988. J. Assoc. Off. Anal. Chem. 71 748-760.

Entz, R.C., and G.W. Diachenko, 1988. Food Addit. Contam. 5 267-276.

Entz, R.C., K.W. Thomas, and G.W. Diachenko, 1982. J. Agric. Food Chem. 30 846-849.

Heikes, D.L, 1987. J. Assoc. Off. Anal. Chem. 70 215-226.

Miller, L.J., and A.D. Uhler, 1988. Bull. Environ. Contam. Toxicol. 41 469-474.

Reinhard, K., W. Dulson, and M. Exner, 1989. Zbl. Hyg. 189 111-116.

Uhler, A.D., and G.W. Diachenko, 1987. Bull. Environ. Contam. Toxicol. 39 601-607.

Vieths, S., W. Blaas, M. Fischer, C. Krause, R. Matissek, I. Mehlitz, and R. Weber, 1988. Z. Lebensm. Unters. Forsch. 186 393-397.

Vieths, S., W. Blaas, M. Fischer, C. Krause, I. Mehlitz, and R. Weber, 1987. Z. Lebensm. Unters. Forsch. 185 267-270.

Investigations of Indoor Air Contamination in Residences above Drycleaning Establishments

Judy S. Schreiber, Ph.D.
Bureau of Toxic Substance Assessment
New York State Department of Health

Dr. Schreiber is a senior research scientist at the New York State Department of Health with extensive experience in assessing human exposure and health risks related to chemicals. She is actively involved in efforts to improve the indoor air quality in buildings where drycleaning establishments are located. Dr. Schreiber holds a doctorate in environmental health and toxicology from the State University of New York's School of Public Health.

I would like to begin this presentation with some recommendations that the New York State Department of Health made to the EPA on its proposed regulation covering drycleaning operations under the Clean Air Act. In its 1987 report entitled *Unfinished Business*, the EPA Science Advisory Board recommended that the EPA target its environmental protection efforts on the basis of opportunities for the greatest reductions in risk. The board found, however, that the EPA lacked pertinent exposure data, making it extremely difficult to assess human health risks. I would like to report on the results of a study we conducted in the Albany area to measure the levels of tetrachloroethene in apartments located above drycleaning establishments. The results of the study show that residents living in apartments above drycleaning establishments are exposed to very high concentrations of tetrachloroethene. Residential indoor air contamination from drycleaning facilities is not addressed in the proposed regulation of drycleaners under the Clean Air Act. Consistent with the recommendations of the Science Advisory Board,

Table 1. Results of sorbent tube sampling for tetrachloroethene (Mahopac, NY).

Location	Results[4] (micrograms per cubic meter)			
	10/18/89[1]	11/6/89[2,3]	12/1/89[1]	4/12/90[2]
Apt. 1E, Second Floor (bedroom)	197,000	14,500[3a] 41,200[3b]	5,500	2,600
Outdoor (window ledge)	1,900	1,780	5,300	832
Apt. 1C, Second Floor	5,300	3,370	5,000	–[5]
First Floor Apt.	–	40	–	–
Third Floor Apt.	–	36	6,600	–

[1] Drycleaning machines in operation during sampling.
[2] Drycleaning machines not in operation during sampling; pressing on-going.
[3] Small spill of tetrachloroethene during sampling period.
[3a] Sample taken before small spill of tetrachloroethene.
[3b] Sample taken before and after spill.
[4] Sample collection times ranged from about 1.5 to 4 hours.
[5] Dash (–) indicates sample not collected at this location.

environmental protection efforts should be targeted by the EPA to reduce exposures and related risks.

We initiated the study as a result of finding elevated tetrachlorethene concentrations measured in an apartment above a drycleaning facility in Mahopac, New York (Table 1). The results of our investigations and studies in residences above drycleaning establishments provide the exposure data necessary to assess the health risks to these residents. I believe that the projected public health risks are significant. We are particularly concerned because residents can be exposed up to 24 hours a day. Certain segments of the population that may be at increased risk—such as the chronically ill, the elderly, infants, and children, and pregnant or lactating women—tend to spend a majority of their time at home. The degree to which residents may be exposed to tetrachloroethene in their homes is related to the practices of the drycleaner, the types of machines used for cleaning, building characteristics, and the proximity of the residents to the drycleaning facility.

The small drycleaning establishment located in Mahopac, New York, which is upstate, is located next to a pharmacy with apartment units above. We first looked into this situation as a result of complaints received from the residents of the apartments. Samples were taken in the bedroom where an infant resides directly above the drycleaning shop.

In that bedroom we found a level of 197,000 $\mu g/m^3$* in indoor air based on a sample of about four hours duration. On the window ledge outside of the building we measured 1,900 $\mu g/m^3$ and in the second floor there was a lower level of 5,300 $\mu g/m^3$. For comparison, in our Albany study we found a background level of tetrachloroethene in indoor residential air of 28 $\mu g/m^3$.

The first set of samples was taken in the apartment while drycleaning machines were operating downstairs. The next set of samples was taken when drycleaning was not being carried out. The drycleaning operations had stopped because the Putnam County Health Department—acting on our recommendation—had closed the drycleaning shop because of the nuisance and health impact on the residents in the building. A level of 14,500 $\mu g/m^3$ tetrachloroethene was measured while pressing but no active drycleaning was being carried out in the facility below. It happened that during the time we were gathering our sample there was a small spill of tetrachloroethene in the drycleaning facility that we detected very clearly in the apartment above, where we measured 41,000 $\mu g/m^3$ several hours after. Clearly even small spills can have a significant impact on the indoor air quality of residences above a facility.

*1 ppm = 6,890 $\mu g/m^3$ or 6.89 mg/m^3

After measuring very high levels at this particular location we became interested in whether our findings were typical for apartments located in buildings where drycleaners operate. Thus we decided to undertake a study in the Albany area, looking at apartments located above drycleaning establishments.

For this study we gathered two 12 hour samples, using evacuated canister samples that our laboratory set up so that when one canister had completed a 12 hour sampling it would automatically switch over to the next one for the second 12 hour period. We took samples consecutively from 7 a.m. to 7 p.m. (called the daytime sample), and from 7 p.m. to 7 a.m. (the nighttime sample).

At one of the drycleaning establishments that we studied, the vent pipe was exhausting directly out of the building at the first floor level, directly below apartment units. It is easy to understand how such an arrangement can contribute to the levels of contaminated air we found in the apartments above drycleaners. As indicated in the report that was circulated (see Supplemental Material appendix), the Health Department worked with our State Department of Environmental Conservation staff to make various measurements and observations at drycleaning establishments as well as in the apartments above. We then tried to correlate the conditions in the drycleaners (including, for example the type of machinery that was used) and the air quality results that we found in the apartments above. In some locations leaky vent pipes were held together with socks—not quite an air-tight approach.

Table 2. Tetrachloroethene concentrations for study and control residences ($\mu g/m^3$).

Residence	Tetrachloroethene Indoor		Tetrachloroethene Outdoor	
	AM	PM	AM	PM
Study Homes				
Residence 1 (O)	55,000	36,500	2,600	360
Residence 2 (T)	17,000	14,000	1,400	1,400
Residence 3 (T)	3,850	8,380	530	812
Residence 4 (T)	1,730	1,350	1,110	441
Residence 5 (D)	440	160	195	66
Residence 6 (D)	300	100	300	400
Control homes				
Residence C1	<6.7	<6.7	<6.7	<6.7
Residence C2	103	77	21	<6.7
Residence C3	<6.7	<6.7	<6.7	<6.7
Residence C4	<6.7	<6.7	<6.7	<6.7
Residence C5	44	56	<6.7	<6.7
Residence C6	9.7	22	16	6.9

Study residence above dry cleaner using:
O = old dry-to-dry unit
D = dry-to-dry unit
T = transfer unit

Source: New York State Department of Health, Bureau of Toxic Substance Assessment.

Table 3. Summary of tetrachloroethene concentrations for study and control residences (μg/m³).

Sample Type/Residence Type (number)	Tetrachloroethene	
	Range	Mean
Indoor Air, AM		
Study homes (6)	300-55,000	13,000
above 'transfer' cleaners (3)	1,730-17,000	7,500
above 'dry-to-dry' cleaners (2)	300-440	370
above old dry-to-dry unit (1)	55,000	55,000
Control homes (6)	<6.7-103	28
Indoor Air, PM		
Study homes (6)	100-36,500	10,000
above 'transfer' cleaners (3)	1,350-14,000	7,900
above 'dry-to-dry' cleaners (2)	100-160	130
above old dry-to-dry unit (1)	36,500	36,500
Control homes (6)	<6.7-77.0	28
Outdoor Air, AM		
Study homes (6)	195-2,600	1,000
outside 'transfer' cleaners (3)	530-1,400	1,000
outside 'dry to dry' cleaners (2)	195-300	250
outside old dry-to-dry unit (1)	2,600	2,600
Control homes (6)	<6.7-21	8.4
Outdoor Air, PM		
Study homes (6)	66-1,400	580
outside 'transfer' cleaners (3)	441-1400	880
outside 'dry-to-dry' cleaners (2)	66-400	230
outside old dry to dry unit (1)	360	360
Control homes (6)	<6.7-6.9	3.9

Source: New York State Department of Health, Bureau of Toxic Substance Assessment.

A summary of the results from this study are shown in Tables 2 and 3. The six study apartments were the only units in the Albany area located in buildings where active drycleaning operations using tetrachlorethene are carried out. Several more that are in buildings where drycleaners use Stoddard solvent were not evaluated at the time because we were specifically evaluating tetrachloroethene. The first residence studied is located above a drycleaning establishment using an older model dry-to-dry unit in very poor operating condition. The gaskets were not functioning properly, and it was a very poorly maintained and operated machine. The second, third, and fourth residences are located above drycleaners using transfer machines. The last two residences are above drycleaning establishments using dry-to-dry machines.

Clearly the indoor air in the apartment building with the old dry-to-dry unit (Residence 1) had very high levels of tetrachloroethene. In the daytime sample, we measured 55,000 μg/m³ tetrachloroethene, which decreased to 36,500 μg/m³ at night. This was a consistent trend. Although the contaminant levels decreased at night, the levels remained quite elevated. In Residence 3, levels were higher at night than in the daytime. We called back to this particular drycleaner to see whether perhaps the owners were running some loads of drycleaning in the evening, and were told they were not; I do not have an explanation for why the night sample is higher than the daytime sample. In most residences the levels at night stayed about 40 to 80 percent of what they were in the daytime period. At the time, we were very surprised by this finding, since we had expected that levels in the apartments would be elevated during the daytime period, when active drycleaning was being carried out, and would drop substantially at night. For the most part this did not occur. Table 3 shows some of the daytime and nighttime average levels that we used as a basis for our risk and exposure assessments.

Also of note is that the indoor levels were consistently higher than the outdoor levels. While this alone is not surprising, it is interesting that some of the outdoor levels also were considerably elevated. The outdoor samples were taken using tubing extended out of the apartment to 3 or 4 feet away from the building (the complete methodology is presented in the report). In general, the contaminant levels followed the same patterns outdoors as indoors.

It is important to understand that although a particular drycleaning operation may consume very small amounts of solvent compared to large industries that consume tens of thousands of gallons of solvents, drycleaners can have a significant impact on the indoor air quality of nearby residences. Some drycleaners may only use a few hundred gallons of solvent per year, but the small solvent consumer can have a very large local impact. Whether the drycleaner operation is consuming 200 to 300 gallons per year of solvent (the cutoffs in the proposed EPA regulations) matters little with regard to the impact on residences.

Six control homes were evaluated at the same time as the study residences using the same methodology—two consecutive 12 hour samples. Our detection level is 6.7 μg/m³. The contamination levels in control residences were consistently and significantly lower than in the study residences. The highest indoor air tetrachloroethene measurement for the control residence was 103 μg/m³. The 24 hour mean for the six control residences was 28 μg/m³. Table 3 shows the range and mean values for the study residences by machine type used in the drycleaning establishment. The three apartments located above cleaners with transfer machines had a 24-hour indoor contaminant level of 7,500 tetrachloroethene. The apartment over the one older model dry-to-dry unit had levels of tetrachloroethene of 45,750 μg/m³ for the 24 hour average. Apartments above the well-run dry-to-dry cleaners had the lowest tetrachloroethene levels of the study apartments, with a 24 hour mean concentration of 250 μg/m³. Table 4 shows data from studies conducted at apartments in a Manhattan high-rise building and Table 5 shows data from a high-rise building in Yonkers. Both buildings were found to have elevated tetrachlorethene concentrations on floors well above the drycleaning operation.

In some cases residential levels were found to be higher than levels measured in areas where workers were pressing clothes and areas where others were staffing the customer counter. A National Institute of Occupational Safety and Health (NIOSH) study cites an average exposure of about 40 mg/m³ (40,000 μg/m³) for those workers. Apartment residents can be

Table 4. Results of Manhattan high-rise residential building sampling (September 1991) (μg/m^3).

Location	AM	PM
Second floor indoor	62,000	48,000
Second floor indoor	7,600	16,000
Fourth floor indoor	5,700	1,200
Seventh floor indoor	2,600	400
Twelfth floor indoor	6,000	5,900
Second floor outdoor	6,700	3,900
Twelfth floor outdoor	1,900	450

Table 5. Results of Yonkers high-rise residential building sampling (August 1991) (μg/m^3).

Location	AM	PM
Study – First floor	226	157
Study – Third floor	609	918
Study – Fourth floor	426	271
Study – Outdoor	189	174
Control – Second floor	51	44
Control – Outdoor	29	47

subject to an exposure duration three times longer than workers experience in a drycleaning shop. Theoretically, people who work in drycleaning shops are exposed eight to ten hours per day. Residents, however—possibly a mother and newborn—could have an exposure period of 24 hours per day. Therefore, a resident could have an occupational level of exposure with three times the occupational exposure time. We are concerned about the residential exposures in apartments, especially those above drycleaning facilities using transfer machines or older model, poorly maintained dry-to-dry machines.

The control apartments in our study had an average of 28 μg/m^3, which is consistent with other studies. For instance, Dr. Lance Wallace, who did a lot of work on the TEAM studies looking at indoor and outdoor levels of various contaminants in background populations, found an average of 27 μg/m^3 in the several hundred homes studied across the country. Our results are in agreement with his measurements for control residents. Thus we feel confident that the information that we generated in our study is accurate. Indeed, we were surprised at the magnitude of exposure in some apartments.

The odor threshold for tetrachloroethene is a very unreliable indicator of exposure. It is cited as ranging from 5 to 50 ppm, or about 35,000 μg/m^3 and greater—well above what we believe is acceptable in apartments. If a person calls and complains about periodic odors in an apartment, it is likely that the average levels in the residence are at least over 1,000 μg/m^3, and probably above 10,000 μg/m^3. This points out the insidious nature of exposure to emissions from drycleaning operations. People may be exposed to moderate to high levels of emissions but not recognize that exposure is taking place since often the odor is not detectable.

In the Albany study we looked at various routes of transport for the tetrachloroethene from the drycleaning establishment to the apartment and found that building characteristics such as pipe chases, air vents, stairwells, and missing ceiling tiles can be a factor. Hot water pipes that go from one level of a building to another level provide a very effective route for the solvent vapors to follow. A chimney effect results because air and heat travel up and throughout the building. Among the parameters we measured, the tetrachloroethene concentration at the pressing station in the drycleaning facility was the best predictor of the concentration found in the residence above.

Since we have not conducted studies on horizontal mapping, I cannot show what the isopleth of tetrachloroethene levels would look like if there were 20 apartments on each floor. Since each apartment building and air management system is different, as are the operation and maintenance practices in the drycleaning establishments, it is very difficult to predict contaminant levels without direct measurement. Unfortunately, the evaluation of individual drycleaners and building characteristics is very time-consuming. So far our investigations have involved our county health departments and the health department in New York City. It takes a lot of staff time to go in, make an assessment of the drycleaning operation, take a look at the apartments, and take some air measurements. We really need some assistance—I believe from the EPA—in organizing an effort to take a closer look at some of these residential exposures. Some of the drycleaning establishments—if they are operated properly and have good controls, if the owners don't leave open vats of solvent around, if they change their filters and have a adequate ventilation and a good machine—can be good neighbors. But there also certainly is a problem with contamination of air in apartments coupled with a large potentially exposed population, and we believe that to be a very critical area that we need to look at more closely.

Finally, with regard to Dr. Diachenko's presentation, I have done some work looking at maternal airborne exposures and modeled what might result in breast milk. Using pharmacokinetic techniques for modeling a mother's inhalation of solvents and the distribution through tissue, and making some estimates of tissue concentrations, I have developed estimates of levels of tetrachloroethene that might be found in breast milk. These estimates are consistent with the results of two studies in which tetrachloroethene was measured in breast milk. I think this is another area deserving of investigation and study.

There are no studies that have looked at neurological effects or other noncancer health effect endpoints in infants and children who live in apartments where they are exposed to very high solvent emission levels in the critical first two years of life, when there is a very real possibility of both acute and chronic central nervous system effects. I think environmental and public health officials have an obligation to take a look at this problem. I urge EPA to see if funding is available for such a study.

Roundtable Discussion Summary: Food and Resident Exposure Reduction

Discussion about food and resident exposure reduction focused on the means through which perchloroethylene vapors enter into apartments and food establishments, and on the potential risks to persons exposed in apartments.

Edward Stein of the Occupational Safety and Health Administration (OSHA) asked whether the New York State study had measured exposures of workers in the drycleaning shop as well as residents in upstairs apartments. Judy Schreiber of the New York State Department of Health responded that worker exposures had been measured as part of the study, but that they were more interested in exposures of apartment residents. Their focus on apartment residents was due to several factors, such as (1) residents may be more sensitive than the average worker (e.g., pregnant mothers, invalids); (2) residents may be exposed for longer periods than the average worker; and (3) unlike most workers, apartment residents may be unaware that they are being exposed.

Steve Risotto of the Center for Emissions Control asked about the routes by which perc moves into upstairs apartments. Dr. Schreiber indicated that there are a variety of potential routes, including ventilation shafts, stairwells, holes in ceilings, pipe chases, and elevator shafts. The limited number of facilities examined so far in the Albany study, however, did not permit any conclusions to be drawn. Mr. Risotto also asked whether elevated concentrations in upstairs apartments had been correlated with high levels in the drycleaning shop, or whether solvent spills may have been a factor. Dr. Schreiber responded that, based on some preliminary statistical evaluation, the perc levels at the pressing station were the best predictors of the levels measured in upstairs apartments, and so they did correlate well with the levels in the shop downstairs. More extensive sampling and investigation to be conducted at facilities in New York City with the New York City Department of Health should provide better data.

Bruce Tichenor of EPA pointed out that studies done in high-rise buildings had found elevated levels of radon gas in upper level apartments. This indicates a possible general tendency for airborne pollutants to spread from lower levels throughout these types of buildings.

Dr. Schreiber discussed risk modeling she had performed based on concentrations measured in apartments in Albany. Her models predicted average concentrations of 6.2 μ/l to a maximum of 3,000 μ/l. Previous studies of nursing mothers had found concentrations of perc ranging from non-detect to 43 μ/l. Her models also indicate that occupationally exposed women could accumulate breast-milk concentrations of up to 8,000 μ/l. A paper based on this modeling will soon appear in Risk Analysis Journal.

Dr. Stein asked whether any medial or health surveys had been performed among residents living upstairs from drycleaners. Dr. Schreiber responded that, to her knowledge, none had been done so far. She further suggested that there is a definite need for such a study, particularly among children living in such apartments, and that New York State would be happy to work with any federal agency interested in sponsoring such an investigation.

Bill Seitz of the Neighborhood Cleaners Association pointed out that in all cases where drycleaners had been shut down by the state because of concern for apartment residents, the operators had been able to make the necessary repairs or equipment modifications and had been permitted to reopen. Dr.

Schreiber confirmed that this was in fact true, and illustrated the fact that the problem can be solved without major expenses.

Dr. Schreiber commented that one additional finding of the New York State study concerned the absorption of perc by carpeting, wallboard, tiles, and other building materials. After shutting down several facilities, elevated perc levels could still be detected for some time, suggesting that building materials can act as a sink for the solvent vapors. She indicated that it is also the case that elevated body burdens of perc take some time to fall to background levels following withdrawal from the exposure source.

Ground-Water Contamination

Investigations of Ground-Water Contamination by Perchloroethylene in California's Central Valley

Wendy L. Cohen
California Regional Water Quality Control Board

Ms. Cohen, a registered civil engineer, oversees inspections, investigations, and the cleanup of leaking underground tanks at bulk fuel terminals for the California Regional Water Quality Control Board, Central Valley Region. Recently she directed a program for determining the sources of volatile organic compounds in municipal water supply wells. She is chairwoman of the American Society of Civil Engineers' Ground Water Committee, and holds an M.S. in civil engineering and a B.A. in environmental sciences from the University of California.

There are nine Regional Water Quality Control Boards in California divided along the state's hydrologic boundaries, and I work for the Central Valley Region, which covers the largest area. The boards implement the state Porter-Cologne Water Quality Control Act and the federal Clean Water Act.

A 1984 state law required all municipal water systems using ground water and serving more than five connections to test their water for volatile organic compounds (VOCs). To date, more than 750 wells in the Central Valley have shown confirmed levels of VOCs. More than 35 percent of those wells contain perchloroethylene (PCE), many of them with levels above the drinking water standard of 5 ppb. The polluted wells are found throughout the region in cities that are totally dependent on ground water for their water supply (Figure 1).

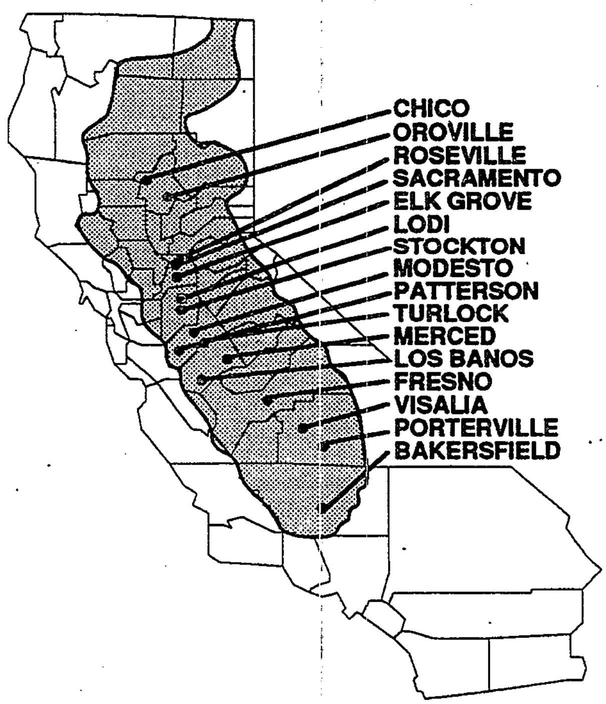


Figure 1. California Central Valley cities with municipal wells degraded by PCE.

We have investigated the sources of PCE in several of these cities by inspecting PCE users, conducting soil gas surveys, and sampling sewers and have identified the likely PCE source in 21 wells. For 20 of those, the likely source is drycleaning operations, which are the only large-quantity users of PCE in the areas of these investigations. Most of these Central Valley cities do not have industries that use large volumes of PCE. Pollution in the twenty-first well, however, was caused by an industrial facility.

We have conducted passive soil gas surveys in several of these cities using a glass tube containing a wire coated with charcoal adsorbent placed about 12 inches below the ground, with the open end down, for about six weeks (Figure 2). Vapors in the soil enter the tube and adhere to the adsorbent. The sample is then analyzed in the lab by gas chromatography/mass spectrometry. Rather than yielding results in actual concentrations, the tests provide PCE ion counts, with higher counts correlating to higher concentrations.

Wherever ion counts exceed 100,000 and monitoring wells were installed, PCE levels in ground water have exceeded the drinking water standard. The soil gas survey is used exclusively for screening. Once a high PCE area is identified, more definitive investigative techniques are used, such as monitoring of the well installation.

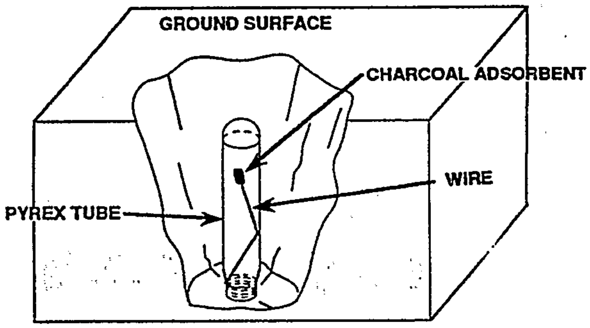


Figure 2. Illustration of soil gas tube device used for sample gathering.

One of our surveys was carried out in Modesto, where a third of the city's wells contain PCE (Figure 3). The darker shading on the map indicates areas of higher PCE ion counts, and the crosshatching shows the sewer lines. This and our other surveys were conducted in residential and retail areas with little or no industry, to eliminate the possibility that large quantity users of PCE could have caused the pollution. If other PCE sources were present, they would be found with the soil gas survey. However, the only place we have found high PCE in soil gas is at drycleaning establishments.

At one drycleaning establishment (Ideal Cleaners), the ground-water gradient is to the south, so we would expect the pollution to migrate in that direction. However, notice that an arm of high PCE that was detected in soil gas testing is heading west. Looking more closely, one can see that the PCE is following the sewer line. At another drycleaning establishment, one arm of the PCE plume is pulled to City Well 11, while another one moves west along the sewer line.

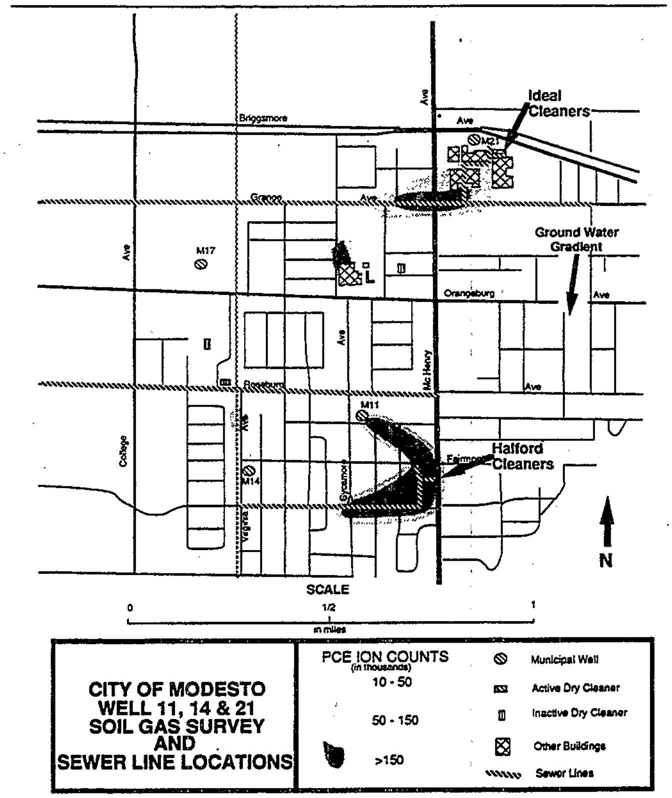


Figure 3. Soil gas survey results for Modesto, California.

Figure 4 shows four drycleaning operations in downtown Merced. At Merced Laundry (far right on

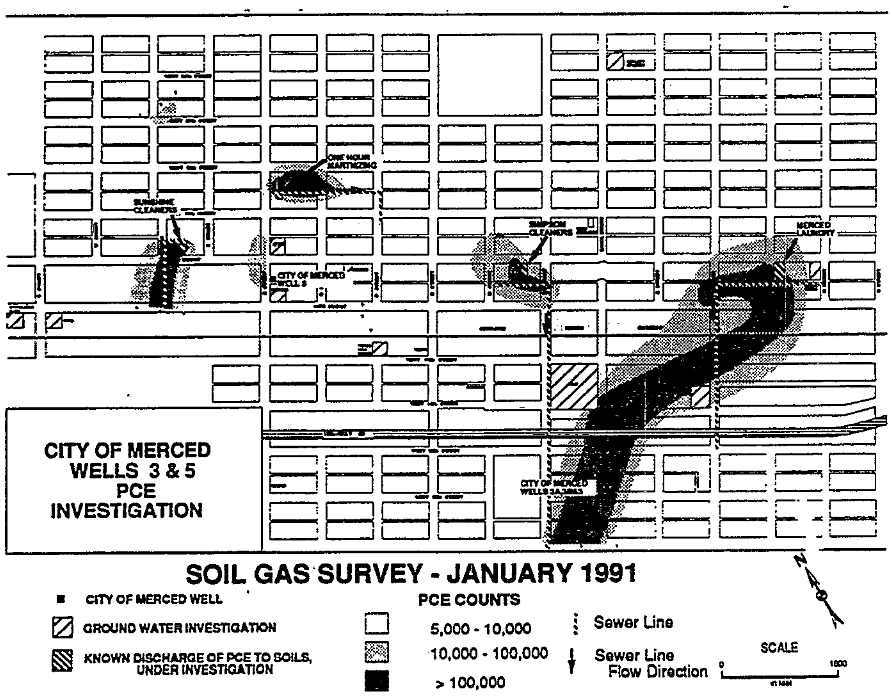


Figure 4. Soil gas survey results for Merced, California.

map), the ground-water gradient is southwest, as indicated by the large plume on the map. There is also an arm of the plume heading west along the sewer line. At Simpson Cleaners (center of map), the ground-water gradient is to the northwest, but an arm of the plume heads the other way. The same pattern obtains for the other two drycleaning shops, where arms of the plumes go in a direction opposite to the ground-water flow. We have seen similar results from other cities, and the results have been duplicated in surveys done by other agencies.

In sewer sampling, we take ambient samples upgradient and downgradient of the drycleaning establishment lateral and then take a flush sample (Figure 5). For the flush sample, a large quantity of water is added to the upgradient sewer access to stir up the bottom sediments, and the sample is taken at the downgradient access when the surge of water reaches that point.

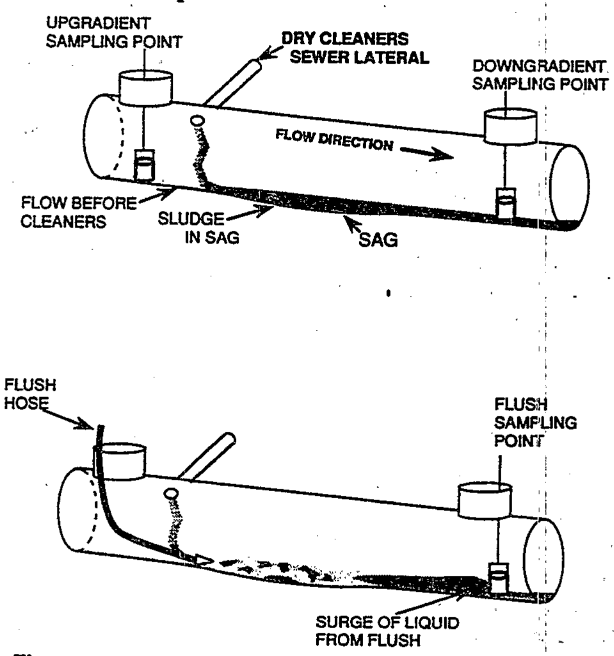


Figure 5. Illustration of sewer pipe sampling points.

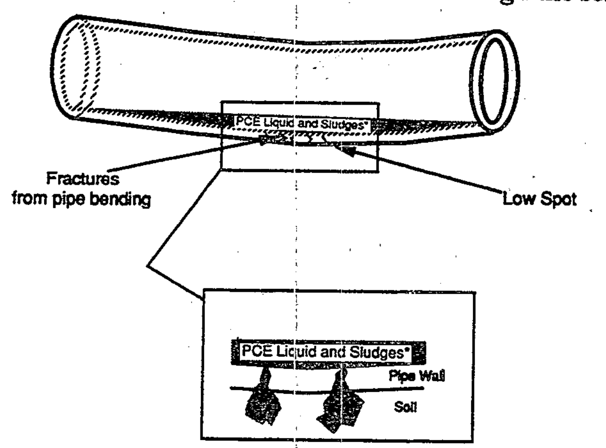
The results of the sewer sampling show that the PCE concentration in the downgradient ambient sample always exceeded that in the upgradient sample. In most of the testing, we found no PCE in the upgradient sample.

In the flush sample, since so much water is added, one would expect the concentration to decrease because of dilution. Instead the PCE level in the flush sample almost always exceeds that of the downgradient sample—sometimes significantly—indicating that PCE liquids or sludges are sitting on the bottom of the sewer line.

Based on our field work and research, there are several likely methods by which PCE migrates out of the sewer. In sewer line videotapes from several Central Valley cities, we often see low spots, cracks, and/or separations at joints. Since PCE is heavier than water, it tends to settle in these low spots. PCE also is attracted to organic material, which also tends to settles in the low spots. Sewer sampling results confirm the presence of PCE in sewer lines.

PCE can leave a sewer line through cracks in the pipe or through the pipe joints. Even in sewers without cracks, PCE in the low spots can easily penetrate the sewer pipe walls, which in the Central Valley are mostly made of clay (Figure 6).

In the scenario shown in Figure 7, PCE liquid penetrates the pipe walls, then sinks through the soil



* PCE Liquid - refers to high PCE concentration liquids, may be pure product

Figure 6. Illustration of small fractures caused by sewer pipe bending.

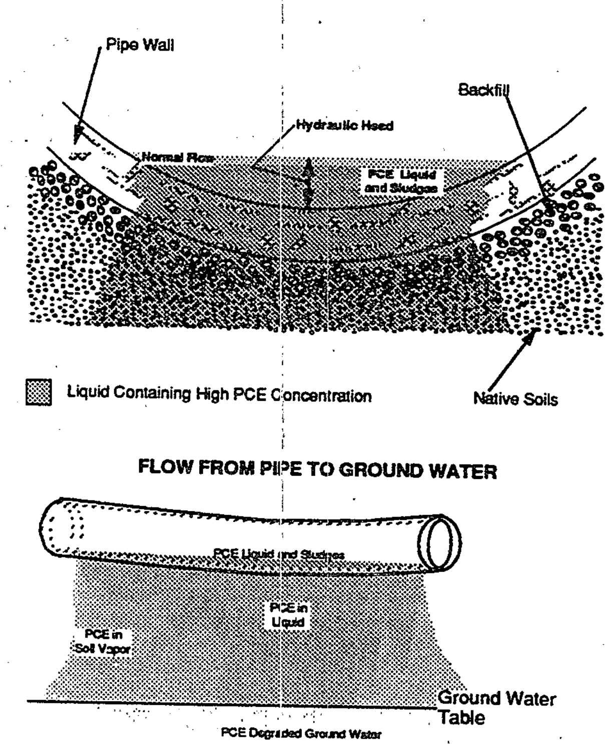


Figure 7. PCE sewer pipe exfiltration: PCE in liquid phase.

in liquid and vapor form to the ground water. In the scenario shown in Figure 8, the PCE penetrates the walls, then volatilizes off the outer edge and sinks through the soil in vapor form to the ground water. Finally (Figure 9), PCE can volatilize inside the pipe and pass through the pipe walls as a gas, which sewer pipes are not designed to contain.

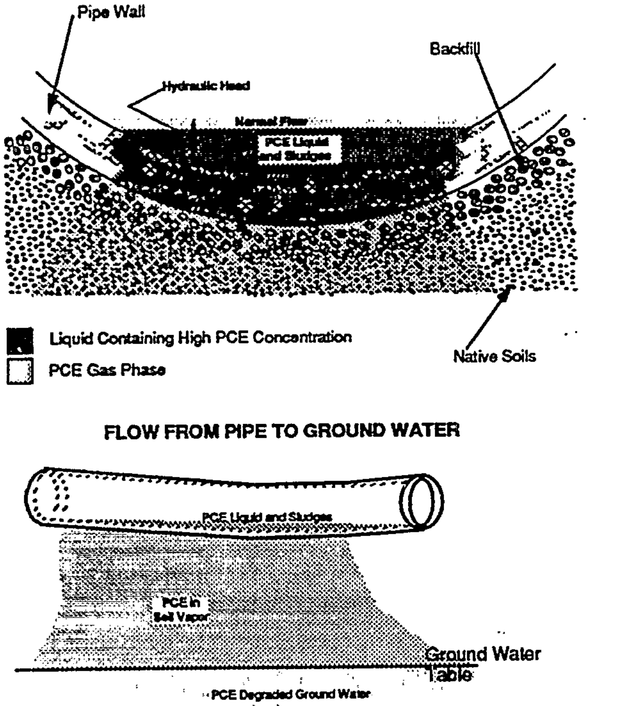


Figure 8. PCE sewer pipe exfiltration: PCE enters the pipe wall as a liquid and the soil as a gas.

This describes just a few of the Central Valley Regional Board's investigations. Similar studies have been conducted in Modesto by EPA Region 9 and in Chico by Cal/EPA, Department of Toxic Substances Control. Both of these comprehensive, area-wide studies reach the same conclusion: drycleaning operations are the major source of PCE in ground water in the study areas, and the PCE is reaching the ground water by migrating out of the sewer.

Clearly a considerable amount of ground water is polluted by PCE as a result of drycleaners discharging their wastewater to sewer systems—and it is not just in California. Water supply wells have been shut down in several cities in Florida, for instance, and many more in other states where testing may not have been carried out yet are likely to be polluted. There is technology available to allow drycleaners to treat the wastewater through evaporation and then treat the vapors with carbon adsorption so that PCE is not discharged to the water or air. There needs to be a prohibition on discharges of drycleaning wastewater to the sewer.

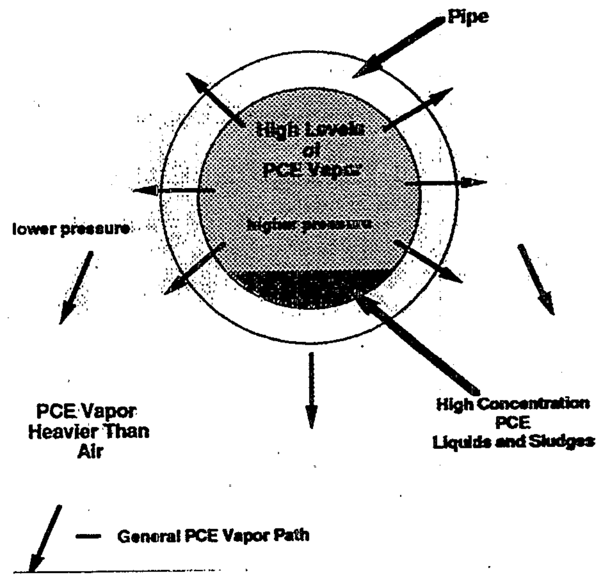


Figure 9. PCE sewer pipe exfiltration: PCE penetrates pipe as a gas.

Even if such a prohibition is enacted, however, past ground-water contamination from many years of drycleaner discharges remains to be cleaned up. Polluted water supply wells must be shut down or their water treated. In Turlock, California, City Well No. 5 was shut down due to PCE contamination. In Modesto, California, the city spent $500,000 to install treatment systems on two of its supply wells, because no one else will clean up the ground water. Therefore, at present, the task of cleanup is falling to the water supply agencies.

Perchloroethylene Ground-Water Contamination in California: The Drycleaning Industry's Perspective

Barry L. Bunte
California Fabricare Institute

In his role as executive director of the California Fabricare Institute, Mr. Bunte represents the drycleaning industry on a range of issues that includes regulation. He has over 25 years of business management experience, 14 of which were spent working with trade associations. Mr. Bunte holds a B.A. in international business from San Francisco State University and has carried out studies in international finance.

Drycleaners in California have been subjected to administrative orders that require them to investigate the extent of PCE contamination and to prepare remedial plans at a potential cost of millions of dollars.

The Regional Water Quality Control Board Investigation in the Central Valley

Agriculture has always been the dominant activity in the Central Valley of California. Therefore, the Central Valley Regional Water Quality Control Board was somewhat surprised to find that certain industrial solvents were present in a number of water supply wells throughout the region when it initiated its Well Investigation Program in 1987. Tetrachloroethylene (also known as perchloroethylene, PCE, or perc) was one of the solvents detected.

PCE is a relatively simple chemical compound consisting of two carbon atoms and four chlorine atoms and is a very effective degreasing agent. However, PCE is a suspected human carcinogen and in recent years less-toxic substitutes have been found for some applications. The drycleaning industry has experimented with many alternative cleaning fluids, but to date all potential substitutes have proven to be environmentally dangerous and ineffective cleaning agents.

Despite other PCE sources in the region, such as vehicle and agricultural equipment maintenance shops and home use products, the Regional Board targeted drycleaners for its initial enforcement efforts.

The Regional Board conducted soil gas surveys using simple buried devices that measure the relative volatile organic compound (VOC) vapors in an area over a period of time. The soil gas surveys indicated that soil and/or ground-water contamination was high in numerous commercial areas. However, this apparent contamination was not limited to the immediate vicinity of drycleaners.

The Sewer Leak Theories

To help explain the observed soil gas concentration patterns, the Regional Board staff developed five "theories on how PCE leaks from sewer lines": (1) through breaks or cracks in the sewer pipe; (2) through pipe joints and other connections; (3) by leaching in liquid form directly through the sewer lines into the vadose zone; (4) by saturating the bottom of the sewer pipe with a high concentration of PCE-containing liquid and then PCE volatilizing from the outer edge of the pipe into the soils; and (5) by penetrating the sewer pipe as a gas.

The Regional Board staff obtained soil and ground-water samples at selected locations and sampled sewer contents directly, both upgradient and downgradient from suspected VOC dischargers. Predictably, there is some disagreement about the strength of the technical case the staff has made given its limited resources. However, the staff is sufficiently convinced that discharges of VOCs from sewer collection systems is a leading cause of ground-water contamination in the Central Valley.

National Repercussions

This issue transcends the Central Valley and the drycleaning industry. If the technical case made by the Central Valley Regional Board staff stands up under further scrutiny, every discharger of VOCs and those discharging heavy metals and other contaminants to sewers could be under investigation for causing regional ground-water contamination problems. In fact, other dischargers already under investigation may seek to transfer their potential liability to the "indirect dischargers"—the industrial users of the local sewer system.

Proposed Cleanup Order—Sacramento

In March 1991 the Regional Board considered issuing a Cleanup and Abatement Order against past and present owners of a drycleaning plant that discharged waste water to the county sewer system. After an emotional hearing that demonstrated that the drycleaning industry does not have deep pockets from which to fund ground-water remediation, the board declined to take action but instructed its staff to investigate bringing drycleaning equipment manufacturers into future cleanup and abatement orders.

Manufacturers Liability

In June 1991, the Regional Board staff met to discuss extending liability to drycleaning equipment manufacturers and others with potentially deep pockets. The staff inspected drycleaning facilities, reviewed manufacturers service manuals and literature, and concluded that "almost all drycleaning equipment, including that at (the drycleaner in Sacramento), is designed to discharge wastewater to the sewer lines." The staff then moved forward in its efforts to tie the drycleaning industry to the ground-water contamination in the Central Valley. However, instead of adding the manufacturers to the cleanup and abatement order in Sacramento, they shifted their efforts to the small city of Turlock.

Proposed Cleanup Order—Turlock

The Regional Board staff then circulated a proposed cleanup and abatement order that named the past and present owners of three drycleaning plants, three equipment manufacturers, and the City of Turlock. All those opposing the proposed order agreed on one point: the Regional Board was exceeding its authority in attempting to regulate discharges to sewers. The manufacturers also argued that they could not be held liable because they had neither knowledge or control of any discharges. The city further argued that it was providing a public service with recognized risks and that the implications of holding local governments strictly liable for any consequences of the services they provide would eliminate many of these services.

Control of Wastewater Discharges

The Federal Clean Water Act forbids discharges to surface water and to municipal and industrial sewers. In California, the California Water Code governs discharges to ground water. These regulatory schemes are separate and distinct.

The Federal Regulatory Scheme

Federal EPA has jurisdiction over both the National Pollutant Discharge Elimination System (NPDES) program for surface water discharges and the pretreatment program for indirect (sewer) discharges. In California, EPA has delegated its authority over the NPDES program to the State Water Resources Control Board and the sewer regional boards. EPA has also authorized various local governments to administer approved sewer pretreatment programs. Regional Boards do not have any authority under federal law to regulate or in any way interfere with discharges to municipal sewers.

The California Regulatory Scheme

Section 13304 of the California Water Code provides that: "Any person who has discharged or discharges waste into the water of this State in violation of any waste discharge requirement or other order or prohibition issued by a regional board or the state board, or who has caused or permitted, causes or permits, or threatens to cause or permit any waste to be discharged or deposited where it is, or probably will be, discharged into the waters of the state and creates, or threatens to create, a condition of pollution or nuisance shall upon order of the regional board clean up such waste or abate the effects thereof or, in the case of threatened pollution or nuisance, take other necessary remedial action."

A discharge directly to surface water or directly to soil where the discharge is likely to leach to the ground-water table could properly be the subject of a cleanup and abatement order. However, the staff's report on its study states that "in most dry cleaners, the only liquid discharge of PCE-containing wastewater is to the sewer lines." With specific reference to the Turlock drycleaners, the staff report confirms that "the only obvious PCE discharges from the three drycleaners were to the sewer." The California Water Code expressly precludes the Regional Board from regulating those who discharge to sewers rather than to surface waters.

Industry Task Force

During the several days of testimony in Turlock, the staff recommended that the manufacturers be removed from the proposed order, apparently convinced they had not "caused or permitted" waste to be discharged. Drycleaners testified that they had always conformed to legal requirements and that discharges had been permitted and approved. Both the city and the drycleaners stated that they were being asked to shoulder a burden that should be assessed against all those who benefitted from the processes and technologies that led to the environmental degradation.

The Fabricare Coalition, a group made up of drycleaning associations, has offered to sponsor a task force consisting of representatives from Cal/EPA, the various state regulatory agencies, and the drycleaning industry. The task force would report to the governor and legislature on the potential environmental impacts of existing practices of the drycleaning industry and on any recommendations for improvements.

Who Pays for the Cleanup

Strict liability is nothing new in environmental enforcement. The basic rationale it that people engaged in hazardous pursuits should be required to answer for all consequences of these pursuits. This may be appropriate when the activity involves nuclear weapons, but the activities that may cause environmental problems run to such mundane activates as drycleaning and automotive repair.

The justification for making responsible large corporations pay for cleanup is that the cost could always be passed on the consumer. However, when this principle is extended to small businesses it breaks down. In the Turlock case, a retired couple who owned and operated one of the cleaners many years ago would have no way to pass along any costs associated with cleanup. Even current drycleaners (which in California typically gross less than $200,000 per year) would find it impossible to recoup million-dollar cleanup costs through surcharges on drycleaning services.

Roundtable Discussion Summary: Ground-Water Contamination

Discussion about ground-water contamination centered on remediation methods and on establishment of mechanisms to cover cleanup costs.

Walther den Otter of TNO Cleaning Techniques Research Institute was asked to describe in more detail the Dutch program for remediation of ground-water contamination due to drycleaners. He explained that the total cost of cleanup averages $50,000 to $100,000. Each cleanup project is broken up into 13 steps. The drycleaner is required to pay an equal amount into a fund for 10 years that will cover the cost of the cleanup. In that way, the costs of cleanup are made more affordable out of typical cashflows. In addition to the cleanup, the drycleaner is required to take all available measures to prevent further pollution.

Jack Lauber of the New York Department of Environmental Conservation asked Mr. den Otter about the anaerobic decomposition process he had described for removing perc from contaminated soil. His concern centered on the finding in the United States that anaerobic breakdown in landfills can lead to formation of vinyl chloride and other volatile organics. Mr. den Otter responded that the Dutch scientists had overcome this problem and that complete mineralization of perc has been demonstrated.

The potential costs of in-ground treatment were raised by Manfred Wentz of R.R. Street. Part of Dr. Wentz's concern is that perc could reinfiltrate the ground water following "cleanup." He raised the question of whether treatment of water at the wellhead (i.e., as it is withdrawn for drinking purposes) would not be more reliable and cost-effective. Wendy Cohen of the California Regional Water Quality Control Board responded that this approach is being used in Turlock, California, and that it is extremely expensive. She prefers that treatment occur at or near the source of contamination, where the volumes requiring treatment would be considerably smaller, rather than drawing the contamination across the aquifer.

In a series of overheads (see Appendix B), Josef Kurz showed three types of ground-water contamination that can occur: (1) in the water unsaturated area (e.g., in soil above the water table), (2) in water saturated areas, and (3) below the water table in the water impermeable area. In Germany, 90 percent of the contamination problems occur in the primary water unsaturated areas. Cleanup in these areas can be performed using relatively simple aeration equipment costing approximately $5,000. The soil is aerated and solvent is recovered from the exhaust stream using activated carbon adsorption. Where contamination occurs in the water saturated areas, remediation is more expensive and involves pumping out the water, purifying it, and returning it to the aquifer.

In response to questions from Bill Seitz of the Neighborhood Cleaners Association, Dr. Kurz indicated that aeration could take from one to one and a half years to complete. The greatest expense is for electricity to run the pump and motors. Costs for maintenance of the carbon beds is not significant.

Ms. Cohen pointed out that while in Germany most of the contamination may occur in unsaturated areas, in California they have found that perc can pass through impermeable barriers such as clay. It may be possible to clean up soil and shallow aquifers and still have significant perc contamination in the deeper water supplies. Dr. Kurz responded that this is not a problem in Germany. Mr. den Otter indicated that in Holland all of the contamination occurs in the water saturated area and that they have developed a small stripping system to remove it.

Tom Gause of the U.S. Small Business Administration enquired about the cost of stripper wells in California. Ms. Cohen indicated that in Modesto the wells cost $200,000 to $300,000 to install and $100,000 per year to change the carbon beds. Again, she stressed that cleaning up near the source of contamination would mean much lower volumes to treat and hence lower costs.

Elizabeth Bourque of the Massachusetts Department of Public Health referenced the comments made by Barry Bunte of the California Fabricare Institute concerning previous agricultural uses of perc in California. Mr. Bunte responded that he was aware of perc usage in agriculture but he did not have any references available with him.

Elden Dickenson of the Michigan Department of Public Health listed numerous uses of perc besides drycleaning. Uniforms or rags brought in from machine shops or auto repair centers may have perc on them if used for parts cleaning or degreasing. When laundered, the perc would be flushed out and discharged with the wash water. Perc was also used at one time for spraying orchards, and cases were cited of companies dumping perc because it could not be used immediately due to weather conditions. Also, perc has traditionally been used very heavily at air bases for cleaning.

Tom Cortina of the Halogenated Solvents Industry Alliance asked whether all industrial pollutants discharged to sewers would not lead to soil and ground-water contamination, given the apparent proclivity of sewers to leak. Ms. Cohen answered that not all contaminants that may leak from the sewer have been shown to penetrate clay and infiltrate ground-water supplies. Heavy metals and VOCs for example, do not do so.

Bill Fisher of the International Fabricare Institute cited figures from the California Central Valley Regional Water Quality Control Board's report suggesting that leakage rates of 100,000 gallons per quarter mile of six-inch pipe are considered "normal."

There was considerable discussion of the current dilemma in the United States concerning disposal of separator water. Manfred Wentz indicated that the industry now recommends that drycleaners do not dispose of separator water to the sewers. Under the proposed NESHAP, however, separator water could not be evaporated to the atmosphere. Scott Lutz of the Bay Area Air Quality Management District pointed out that the only current alternative is to treat the water as hazardous waste and have it hauled away. Alan Phillips of Air Quality Laboratories reported on discussions he had with hazardous waste treatment facility operators in California who indicated that they could not accept all of the separator water generated by the drycleaners they serve. Their disposal capacity could not handle it. Bill Fisher indicated that the industry was trying to work with EPA to gain approval for evaporation. According to him, the quantity of perc involved would range from 1/2 ounce to 5 to 20 ounces per year. Bill Seitz of the Neighborhood Cleaners Association stated that there are numerous devices available to permit the operator to treat separator water onsite, but that the activity would classify the operator as a hazardous waste treatment facility and trigger an expensive permitting process.

Mr. den Otter recommended that drycleaners pay special attention to the delivery of perc to the facility and the transfer process. In Holland, 50 percent of soil and ground-water contamination problems were traced to improper or sloppy transfer operations.

CAPITAL FORMATION

Capital Availability and Profitability Impacts of Drycleaning Regulation

Brenda L. Jellicorse
Center for Economics Research
Research Triangle Institute

Ms. Jellicorse is an economist at the Research Triangle Institute where she has developed financial models for analyzing the impacts of the Clean Air Act on drycleaners, municipal waste combustors, and landfill operations. She holds a B.S. in economics from the University of Texas at Arlington.

Census data indicate that most drycleaning firms—approximately 60 percent—are proprietorships, another 30 percent are corporations, and the remainder are partnerships (Figure 1). Proprietorships and partnerships, which are very similar in structure, thus account for two-thirds of the industry. This is worth noting since the legal form of organization has an impact on the availability of capital.

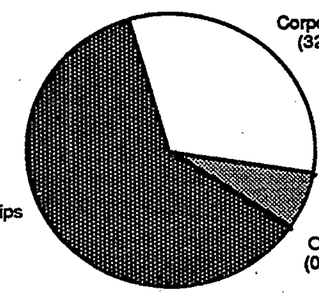


Figure 1. Types of business ownership in the drycleaning industry.

There are approximately 30,000 drycleaning facilities in the United States, and we estimate about 27,000 firms. Thus there are a large number of proprietorships and partnerships in this industry. From the lender's perspective, under a sole proprietor or a partnership form of ownership, the individual is not significantly distinct from the firm. The lender looks at the financial statements and the financial well-being of the individual in conjunction with the business (Table 1). An individual who operates a financially viable drycleaning business but has a problematic personal financial statement may have difficulty obtaining capital. In the same sense, an individual, or partnership, with a strong personal financial statement who owns and operates a drycleaning business that is in financial difficulty may be able to get funding on the basis of personal financial status.

Table 1. Basis of credit worthiness by type of business ownership.

Type of Ownership	Basis for Credit Worthiness	Personal Assets at Risk
Proprietorship	Owner's personal financial status	Yes
Partnership	Owner's personal financial status	Yes
Corporation	Corporation financial status	Maybe

Legally, the individual or the proprietor or the partner is responsible for all of the debts of the firm. Since the owner receives all of the profits and is responsible for the losses, it is not inappropriate for a lender to look at the owner's personal financial statement. While technically lenders do not have legal grounds for attaching the personal assets of an owner when a business is a corporation, some lenders will require the owner or the founder of a corporation to put personal assets on the line as a condition precedent to obtaining a loan. Indeed, this is fairly common for small businesses that are corporations. Thus, it may be that in the drycleaning industry in particular, owners may be less likely to be protected financially by being incorporated.

Another factor germane to any analysis of the availability of capital is the size of the entities under consideration. According to Census Bureau data, a large number of drycleaning firms are making less than $100,000 in annual receipts (Figure 2). It is

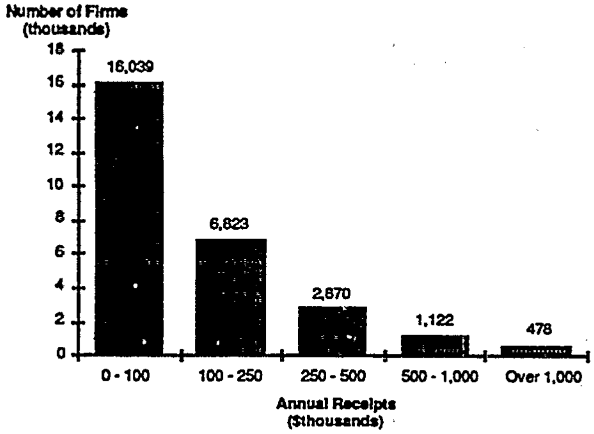


Figure 2. Average annual receipts of drycleaning firms.

difficult to understand how a business can continue to operate with such a low level of receipts. Perhaps a couple supplementing their income or someone who is operating several businesses at once could manage to operate with such low revenues.

When evaluating the ability of drycleaning firms to obtain financing, ratio analysis is useful. It is a conventional way of looking at the financial viability of a business. Dun & Bradstreet (D&B) report financial ratios for drycleaning firms, and in our analysis of the proposed National Emission Standards for Hazardous Air Pollutants (NESHAP) regulation, we looked at these ratios as a way of determining the number of drycleaning firms or the portion of the industry that is likely to have a problem securing funds for financing pollution control equipment.

We examined four categories of ratios. The first is liquidity, which is the measure of the ability of a firm to meet its currently maturing financial obligations. The particular ratio that we used was current assets divided by current liabilities. Most bankers are looking for a ratio of approximately 2 to 1. The average drycleaning firm, however, does not even come up to that level. It appears that above-average firms, at least according to this liquidity ratio, would not have difficulty obtaining conventional financing. Below-average firms apparently would have difficulty meeting their current obligations. If more obligations are added to the currently maturing obligations, these firms are going to experience financial difficulty.

Another way of looking at financial viability is activity. As used here, activity is the ratio of sales to fixed assets. It indicates how effectively or how efficiently the firm is using its resources—in essence, a measure of capacity utilization. Firms with particularly low activity ratios may not be using their equipment to the fullest extent.

Leverage ratios are a bit more complicated because Dun & Bradstreet's criteria indicate that, in terms of advancing a loan to these businesses, less debt is better. Yet too little debt may be an indication that the firm is underutilizing less-expensive methods of financing. Equity financing is typically more costly in terms of the return that is required by the investor. Leverage here is calculated as the ratio of total debt to total assets.

Finally, profitability is measured as the ratio of profit to sales. Below-average firms keep only 1 percent of their revenues, whereas average firms net 7 percent and above-average firms net almost 14 percent. Variations on this profit ratio are included in Table 2. These include profit-to-assets and profit-to-net-worth ratios. These measures provide the same kind of information as profit-to-sales ratios.

Table 2. Baseline financial ratios of drycleaning firms.

	Financial Condition		
	Below Average	Average	Above Average
Liquidity			
Current ratio (times)	0.80	1.73	5.10
Activity			
Fixed asset turnover ratio (times)	2.30	5.56	7.54
Leverage			
Debt ratio (percent)	60.00	45.90	15.00
Profitability			
profit to sales (percent)	1.00	7.00	13.00
profit to assets (percent)	1.40	14.50	32.50
profit to NW (percent)	3.60	26.80	38.20

Source: Duns Analytical Services, 1990.

Profitability indicates not only the ability of a firm to cover the cost of complying with a regulation, but also speaks to the incentive that a firm has to stay in business when faced with the purchase of pollution control equipment. Above-average firms, of course, will have considerable incentive to purchase the equipment and stay in business.

In any industry there are generally two broad sources of funds: debt and equity (Table 3). Debt is typically thought of as less risky for the lender because it involves an actual contractual agreement between the borrower and the lender, and the lender has first rights to repayment. That is, if the business is liquidated, debt holders will receive repayment before equity holders. There are factors as well that

Table 3. Sources of funds for capital investment.

Debt
- Trade Credit
- Bank Loans
- SBA Loans
- Mortgage Loans
- Loans or Credit from Equipment Sellers
- Small Business Investment Company Loans
- Government Sponsored Business Development Loans

Equity
- Personal funds/ retained earnings
- Loans from relatives or friends
- Loans from partners
- Venture capital funding

make debt attractive to the borrower—it costs less and is tax deductible. Consequently, debt financing is common in the drycleaning industry.

Typically, equity financing does not involve a contractual obligation for repayment. Examples of equity include personal funds, loans from relatives, loans from partners, and venture capital. Equity investors tend to require a higher rate of return as compensation for assuming a higher level of risk. Equity funds also may be raised by issuing stock or selling shares in the company, but this is a source of financing that is not generally available to drycleaning firms.

In general, banks will not loan to a drycleaning firm in below-average financial condition. Commercial banks have indicated that they will not loan funds to drycleaning firms unless they are fully confident of the firm's ability to repay the loan.

We calculated the cost of capital for drycleaning firms, using historical weights for the mix of debt and equity that such firms have typically used (Table 4). For above-average firms, the weighted average cost of capital in real after-tax terms is 11 percent. The cost of capital for average firms typically is 12.5 percent, and 15.4 percent for below-average firms.

Table 4. Cost of capital for drycleaning firms.

Financial Status	Debt	WACC	Equity
Below Average	5.3%	15.4%	20%
Average	4.7%	12.5%	16%
Above Average	4.3%	11%	14%
Historical Weights (D & B)	31%		69%

Interestingly, in my discussions with bankers I found them concerned about environmental contamination. Consequently, many banks require that an environmental audit be conducted before a loan to a drycleaning facility is even considered. An environmental audit, however, can cost as much as the pollution control equipment that the drycleaner plans to install.

Figure 3 shows a flow chart of the decision process that an owner would go through when deciding whether to invest in equipment necessary to achieve compliance with a regulation. The first question the owner must answer is, Do expected returns following the compliance expenditures exceed expected costs? If the answer is yes, the owner will not likely close down the facility. If it is no, however, the owner is left with two options: make the investment and keep the facility operating, or sell the business. Either way, the

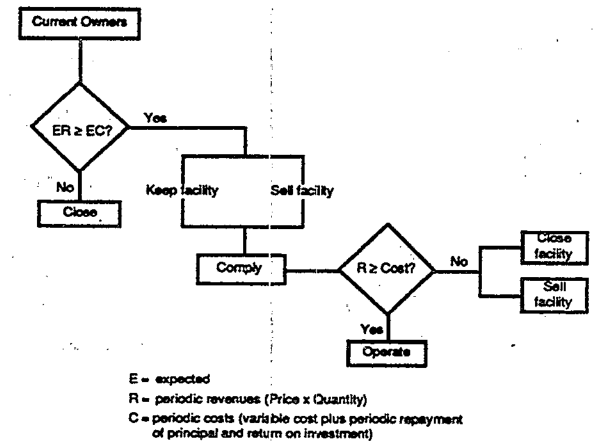


Figure 3. Decision tree for drycleaning operator faced with cost of complying with proposed environmental regulation.

facility must be brought in compliance with the regulation if operations are to continue.

After the investment is made the question becomes, Do actual revenues exceed actual costs? If the answer is yes, then it is likely the facility will stay in operation. If the answer is no, then it is likely the owner will either close the facility or sell it. Thus, there are several points where the owner has to make a decision on whether to continue operations.

In the final analysis, when we look at the profitability impacts and the capital availability impacts, the question becomes, Is it profitable to stay open? Is financing available to cover the cost of complying with the regulation? Or, is there cash on hand to cover the cost if financing is not available?

Based on our studies, as a result of the NESHAP there will be ownership impacts in the drycleaning industry, and ownership changes are likely—such as bankruptcy or forced sale under unfavorable conditions. We projected these impacts based on two financial scenarios. The first assumes that small firms represented the firms in the least favorable financial condition (Figure 4). Indeed, there is a large number of potential changes in ownership under the proposed NESHAP regulation without a size cutoff. With no

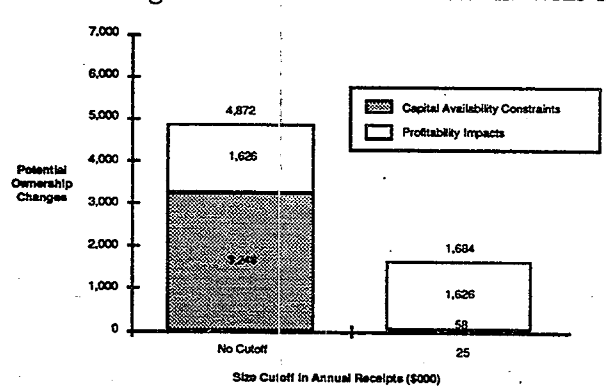


Figure 4. Financial scenario 1: Capital availability and profitability impacts projected under the proposed NESHAP.

small-entity exemption, approximately 5,000 firms would be in financial difficulty, according to our estimates. Although EPA did introduce a cutoff for this proposed NESHAP corresponding to $100,000 in annual receipts, the cutoff is not shown here because it would result in zero closures under this financial scenario.

In another financial scenario we assumed that 25 percent of firms in all receipt-size classes were in poor financial condition (Figure 5). Under this scenario—which does not seem quite as likely—with a $100,000

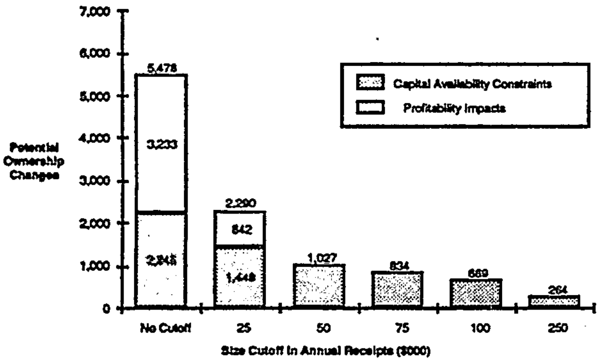


Figure 5. Financial scenario 2: Capital availability and profitability impacts projected under the proposed NESHAP.

receipts cutoff, 669 firms would have difficulty financing the cost of the regulation.

It has been reported that there were approximately 500 bankruptcies in the drycleaning industry in 1990, even without proposed regulations pending. If we are projecting 669 failures, no doubt some of those would already be having serious financial problems.

References

Bass, A., 1991. Commercial Loan Officer, Central Carolina Bank, March 22, 1991. Personal Communication with Donald W. Anderson, Research Triangle Institute.

Behrens, R.H., 1985. *Commercial Loan Officer's Handbook.* Boston: Banker's Publishing Company.

Bowlin, O.D., J.D. Martin, and D.F. Scott, 1990. *Guide to Financial Analysis.* pp. 229-233. New York: McGraw-Hill.

Duns Analytical Services, 1990. *Industry Norms and Key Business Rations.* Dun & Bradstreet Business Credit Services 1989-1990.

Appendix

The following materials were submitted for the roundtable by Ms. Jellicorse but not referred to specifically in her presentation.

FIXED RECURRING COSTS AS A PERCENTAGE OF ANNUAL SALES

Cost Category	Annual Sales: $100K to $200K	$200K to $300K	Over $300K
Wages-fixed component (40%)	19.97%	20.62%	26.87%
Rent or building overhead	7.42%	8.59%	6.89%
Depreciation	7.17%	8.21%	3.92%
Interest and bank charges	4.39%	4.29%	1.04%
Insurance	3.25%	3.72%	2.56%
Administrative expense	1.36%	1.95%	1.32%
Payroll taxes-fixed component (40%)	1.22%	1.41%	1.64%
Total	44.78%	48.80%	44.24%

Source: International Fabricare Institute 1988 Operating Cost Survey

VARIABLE COSTS AS A PERCENTAGE OF SALES

Cost Category	Annual Sales: $100K to $200K	$200K to $300K	Over $300K
Wages-variable component (60%)	17.05%	18.04%	19.31%
Total supply cost	8.69%	7.82%	7.62%
Outside work	8.10%	5.39%	5.22%
Miscellaneous	5.12%	2.40%	3.55%
Advertising	2.45%	1.95%	3.60%
Utility costs-gas & oil	2.03%	2.27%	2.19%
Payroll taxes-variable component (60%)	1.83%	2.12%	2.46%
Repairs & maintenance	1.76%	2.54%	2.24%
Utility costs-electricity	1.51%	1.54%	2.76%
Office expense	1.46%	1.19%	1.15%
Utility costs-water & sewage	0.66%	0.58%	1.06%
Claims	0.52%	0.34%	0.41%
Total	51.18%	46.17%	51.57%

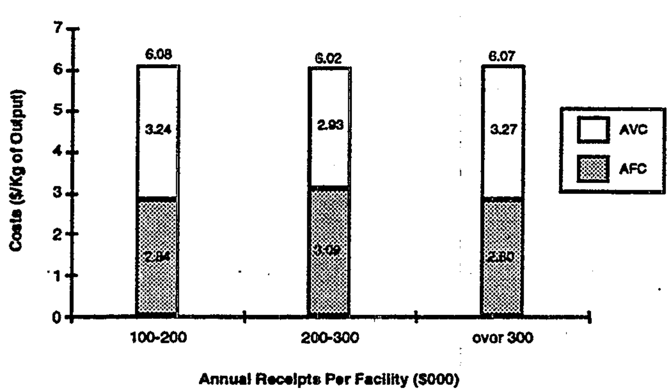
Source: International Fabricare Institute 1988 Operating Cost Survey

OPERATING COSTS FOR TYPICAL DRY CLEANING FACILITIES

	Annual Sales: 150,000	250,000	400,000
Annual Output (kg of clothing cleaned)	23,659	39,432	63,091
Fixed Recurring Costs			
Dollars/kg	2.84	3.09	2.80
Dollars/year	67,167	121,990	176,968
As Percentage of Revenues	44.78%	48.80%	44.24%
Variable Costs			
Dollars/kg	3.24	2.93	3.27
Dollars/year	76,773	115,435	206,272
As Percentage of Revenues	51.18%	46.17%	51.57%
Total Costs			
Dollars/kg	6.08	6.02	6.07
Dollars/year	143,940	237,425	383,240
As Percentage of Revenues	95.96%	94.97%	95.81%

Source: International Fabricare Institute, 1988 Operating Cost Survey

Average Costs For Dry Cleaning Facilities



Cost Impacts on the Drycleaning Industry of Exposure Reduction Alternatives

L. Ross Beard
R.R. Street & Co.

Mr. Beard is chief executive officer of R.R. Street & Co., a major supplier of chemicals, filtration products, and solvent maintenance equipment to the drycleaning industry, and a member of the drycleaning industry's regulatory strategy group. Prior to joining R.R. Street in 1982, Mr. Beard was at Arthur Andersen & Co.'s Management Consulting Division, in Washington, DC, consulting on the cost of federal regulation for the Business Roundtable, the Environmental Protection Agency, Department of Treasury, Small Business Administration, and several major U. S. corporations. Mr. Beard also served as an advisor to the Joint Economic Council and Office of Technology Assessment on the cost impacts of federal regulation.

In order to discuss the cost of complying with federal regulation of the drycleaning industry several basic premises and facts related to the regulation of this industry must be understood.

- While protecting the safety and health of individuals and the environment is rational, desirable, and essential, we must remember that the impetus and organization of programs to achieve these goals is political, and as is the case with most politically driven programs, emotional and political expedience are frequently substituted for balanced, sound policy.

- The process for the development of regulation is an unbalanced and inequitable variant of our civil legal system. Setting aside the increasing criticism of the adversarial approach as the basis of our civil legal system, critical elements to ensure fairness and representation have been omitted in its transfer to the regulatory system. Not the least of these inequities is that when the seemingly unlimited resources of the regulator are pitched against the regulated, an industry like drycleaning—in contrast to the auto industry, for instance—does not have sufficient economic or political power to secure a fair hearing. This regulatory process under which the regulator is judge and jury, instead of objective inquirer, also permits other parties with self-serving interests to intervene to their profit or political advantage with no public record of such intervention.

- The layers and types of costs imposed on this little industry are far greater in scope and magnitude than the cost of equipment. The absence of any accountability of those who regulate or stimulate regulation enables costs to be imposed far greater than intended by the political goals. Even the occurrence of a meeting like this International Roundtable, which incorrectly characterizes the drycleaning industry as polluters, results in costs being imposed on our industry, in addition to the costs to the American taxpayer of conducting such a conference.

In this presentation, I will address the drycleaning industry's efforts to minimize waste and the incremental costs imposed on the industry by regulators, intentionally or not. I will also suggest solutions that would minimize the impact of regulation on this industry. If my assessment of the impact of regulation or the drycleaning industry seems critical, it is intended to be so. There is no need for the achievement of desirable social goals to have such an impact. As the representatives of EPA's Air office can attest, it is possible to achieve the goals of well-intentioned regulation at an acceptable economic cost, if the regulators and regulated cooperate in the formation of regulation. At a state level, Michigan can be held up as an example for its well-balanced regulation, and even California, through a government/industry task force, may achieve a similar goal.

Before considering costs, let us also understand what has driven the increasing regulation of the drycleaning industry—the substance perchloroethylene (perc), which is used by more than 80 percent of the 25,000 family-owned and operated drycleaners in this country. Perc was introduced to the U.S. drycleaning industry more than 45 years ago and quickly gained acceptance because it performed as well or better than any other solvent and also eliminated fire hazards. For many years, transfer machines were used that caused exposure to perc vapors far in excess of the levels of exposure today and levels of exposure contemplated by the Occupational Safety and Health Administration (OSHA) or EPA. There is no persuasive evidence that this exposure resulted in the incidence of cancer or other ailments beyond levels experienced by the general population. Furthermore, faced with the allegations of this substance having serious adverse health effects, families remained in the business of drycleaning using this substance. If there is no conclusive evidence to support the proposition that perc is a probable human carcinogen, coupled with the fact that it is not an ozone depleter or a volatile organic compound (VOC), why then is there so much regulation of the users of the substance?

Like every other industry prior to the 1970s, the drycleaning industry was generating emissions to the atmosphere. Unlike most other industries, the U.S. drycleaning industry has for many years taken a position in support of the social goals promoting a clean environment and safe and healthy working conditions. Drycleaners, distributors, and manufacturers of products used by drycleaners have voluntarily incurred substantial costs to guard the safety and health of the people who work in drycleaning plants (predominantly owners and their families), to protect the environment, and to implement sound work practices. In reaction to public policy against emissions, frugal drycleaners have implemented processes to filter, distill, and reclaim solvent for reuse. As a result, in the past 15 years, the drycleaning industry has implemented measures that have reduced its annual consumption of perc by half. Federal, state, and local governments, however, have established regulations formalizing many beneficial practices already in place and have added a number of regulations—sometimes overlapping, sometimes conflicting with others—that have resulted in substantial capital, operating, and secondary costs.

The drycleaning industry acknowledges that some government intervention in the economy is necessary to achieve desirable social goals. Well-conceived and carefully implemented regulations can be beneficial in establishing standards and codes of practice. The recent cooperative efforts of the drycleaning industry, Congress, and EPA in the formation of stringent but responsible application of the Clean Air Act is a model of good regulatory governance. As a result, environmental objectives are met at a tolerable cost to the industry. This demonstrates that the development of regulation generally requires far greater forethought and analysis to ensure that the social goals and benefits are attainable at an acceptable cost and that the particular regulation is the best and most efficient way of achieving the social goal.

As an industry, we are concerned that the costs imposed by federal regulations are often excessive related to regulatory goals. The framework for regulatory impact analysis at the federal level does not address many secondary costs and, therefore, the real costs of compliance are often understated. More often than not state and local regulatory agencies compound the effects of federal regulation by enacting their own regulations that are more stringent and far reaching than was the intent of the federal regulation. Furthermore, there are numerous examples of state and local authorities implementing regulations and imposing costs for the purpose of generating revenues to sustain their bureaucracies. For example, the State of California is currently seeking to impose a $1,100 per annum license fee on drycleaners who purchase a $2,000 piece of equipment to evaporate waste water, a process that the state favors.

Most troublesome to the drycleaning industry is the flood of regulation at the federal, state, and local levels driven by the mischaracterization by regulators of the health effects of perc. The consequence of regulations arising from this mischaracterization will be the imposition of costs on the drycleaning industry far beyond its capability to absorb them, which forces the industry to attempt to pass them on to the consumer of its services. If this seems like a rhetorical doomsday assessment of the cost of regulation, consider the very strenuous efforts of the California Regional Water Boards to hold drycleaners responsible for the cleanup of contaminated soil resulting from leaks in the municipal sewer systems. As we all know, the preferred method for handling industrial wastewater throughout the United States has been through municipal water treatment facilities. This method provided an economically sensible and reliable means of managing the discharge and cleanup of contaminated industrial wastewaters. This method is accepted and endorsed in federal environmental legislation and regulation as a matter of policy. However, it is and apparently has been known by government authorities that California's sewer systems are designed to leak. Presumably those systems will leak almost anything that is discharged into them, including household waste containing chlorinated solvents such as perchloroethylene.

The attempts to get drycleaners to finance this cleanup is bizarre in the sense that the contamination was allegedly caused by the discharge of minute concentrations of perc in wastewater specifically permitted to be discharged under federal regulation. It is also bizarre to suggest that such contamination is solely the responsibility of the drycleaner, and it is not even remotely conceivable that a drycleaner could bear the costs of cleanup of such contamination. Even the costs of investigatory work in preparation for cleanup would run into decades worth of the average drycleaner's profits. Philosophically, attempts to impose costs of this magnitude on a small business are irrational and offensive. This attempt to force the drycleaning industry into eradicating all perc present in the environment, even if approved by the courts, is "tilting at windmills." There is not enough wealth in the industry either to comply or incur the legal costs of defending such actions.

Drycleaners and their suppliers are small companies whose assets and values are dwarfed by this potential liability. These entities also have very limited liability insurance coverage, most of which will not include such liabilities. While lawyers may prosper as a result of this endeavor, entities in the industry that are involved will be left bankrupt—and the California soil will still not be cleaned up. As a matter of principle, it is also improper to impose costs retroactively. After all, society received these services at a cost consistent with accepted operating practices of the day. Drycleaners made profits consistent with the operating costs of their business when those services were provided. If the intent is to apply the philosophy of Superfund, it is yet one more inappropriate application of a law intended to address an emergency situation. The use of ex post facto law is odious at any time but particularly so when applied to small businesses like drycleaners.

The ability of the drycleaning industry to generate the capital required to invest in equipment for minimizing emissions in compliance with the Clean Air Act is a significant issue, as is the industry's ability to absorb the costs of operating that equipment and maintaining records. This is shown in the regulatory impact analysis. A number of plant closures is projected as a result for those plants with annual revenues of less than $100,000 that would be unable to comply. That same analysis proposes that the average plant with annual revenues greater than $100,000 that is currently profitable will not be affected due to the savings in solvent consumption. This of course assumes that the manufacturers and sellers of perc will not increase the selling price to maintain existing profitability at a reduced level of supply. If that hypothesis does not hold true, the projected number of plant closures may have to be supplemented by the number of plants that would be unable to continue or unwilling to accept the lower returns of staying in business. Consider the fact that this is the projected impact of only one area of regulation, and one where there was a careful and cooperative effort to minimize the economic impact. When the compounded cost impact of compliance with existing, planned, and proposed regulation at all levels is estimated, it will be seen that the average drycleaner cannot comply without passing those costs directly to its customer. As illustrated in the regulatory impact analysis for the Clean Air regulations, the relative costs of drycleaning in the last 15 years have increased consistent with changes in the consumer price index. There is no evidence to suggest that substantial additional costs due to regulation can be recovered in the marketplace for drycleaning services.

Even if it were possible to pass on the directly attributable costs imposed by regulation, no consideration is given to the costs of secondary effects of regulation. These include but are not limited to:

- Loss of productivity
- Disincentive to invest in drycleaning
- Resource misallocation
- Loss of value and equity built in existing drycleaning businesses
- Costs incurred by government in regulating the industry

If the rate of increase of regulation of this industry is left unchecked it is not difficult to contemplate a scenario of large-scale plant closures, unemployment, and loss of capital investment in this industry sector. The people who own and operate drycleaning businesses are typically members of small families. Their skills, abilities, and availability are not automatically transferable to other market sectors, and therefore the real economic costs could be far greater and longer lasting than ordinarily expected.

When the potential contribution of the drycleaning industry to emissions in the U.S. environment is put in perspective, the degree of attention to regulating this industry appears disproportionate to the size of the alleged problem. This is not an industry that emits to such a degree that heavy regulation should be used to attempt to force technological change at an accelerated pace. Furthermore, it can be demonstrated that the drycleaning industry as it is structured in the United States does not have the financial ability to accommodate rapid technological change.

If the potentially catastrophic effects of overregulation of the drycleaning industry are to be avoided it will be necessary to:

- Recognize the disparate impact of regulation on a predominantly "mom and pop"-owned industry in the regulatory impact analysis methodology and incorporate secondary effect assessment
- Restrict the ability of regulators to form regulation based on inadequate, incomplete, and uncertain risk assessment data
- Implement a comprehensive cross-media regulatory system at the federal and state levels

that avoids overlapping and conflicting regulations

- Establish a mechanism that facilitates cooperation between the drycleaning industry and regulators in the achievement of social goals at a socially acceptable cost

It is not naive to expect that these measure can be taken. Our industry educated and worked with Congress and EPA's Air Office in the development of Clean Air Act legislation and regulation. As a result, we have tough but fair regulations that will achieve the social goals of that legislation.

Similarly, at a state level, cooperative efforts such as those of the State of Michigan and the Michigan Institute of Laundry and Drycleaning have resulted in a more balanced regulatory environment, where the parochial social goals of that state can be achieved at an economically reasonable cost.

Third, in California—albeit that legislation was required to accomplish the goal—a joint drycleaning industry and regulatory task force is being established to study the potential pollution effects of the drycleaning industry on the environment and to adopt practices that minimize pollution at acceptable economic cost. This task force includes participation of all sectors of the drycleaning industry in California and all major regulatory agencies in the state involved with the industry, and it is chaired by the newly formed California EPA. Regulators at the federal level should consider this mechanism carefully.

Finally, although this International Roundtable is an interesting format for learning about what is occurring in the drycleaning industry elsewhere in the world, the U.S. regulatory agencies must be extremely cautious about the automatic adoption of "solutions" from Germany or Japan. The social, demographic, and economic structure of the U.S. drycleaning industry is not the same as that of the German or Japanese industries. Furthermore, Germany's and Japan's decisions involving environmental regulation are driven by their own political and economic motivations. Let us also not forget that most European perc is produced outside Germany. Both Germany and Japan are major manufacturers of drycleaning machines and could benefit from a mandated re-equipping of U.S. industry.

Remember also that a meeting similar to this roundtable was held in the 1970s when EPA made its first attempt to address the perceived problem of the drycleaning industry's use of perc. The "solution" was to mandate a process using the Solvent 113 (chlorofluorcarbon) advocated by its vendor DuPont, which had not been successful in introducing it in the free market. Despite the efforts of an eager EPA office over many months, drycleaning industry leaders, some of whom are here today, were persuasive in arguing that the idea had no merit. Had the drycleaning industry been forced to adopt the solvent and purchase the equipment necessary to use it, the economic consequences would have been disastrous. Even so, the legal and other costs of enlightening EPA were large for this industry. In addition, the environmental consequences, according to today's thinking, would be serious. Our industry would now be facing another mandated change of solvent—but to what?

One only needs to look to other countries whose more compliant industries adopted 113 to see the result. A major chain of drycleaners in the United Kingdom who did convert to 113 now has major financial problems as a result of having to replace its equipment twice within a ten year period. Had it not been for its ability to finance these problems with the profits from other lines of business, it probably would not exist even today.

Financing Options for the Drycleaning Industry

Thomas Gause
Small Business Administration

Mr. Gause, a director of business development for the U.S. Small Business Administration, has worked as both a loan officer and program director in SBA offices throughout the country. Before entering the public sector in 1965, he worked in sales, sales management, and public communications for private industry in the United States and in South America.

Well, we have a dilemma: It looks as if we are concerned with the environment and water—which is essential to all life—and on the other hand we are concerned with the importance of a very significant part of our economy, an industry that represents some 30,000 businesses.

So how does the Small Business Administration (SBA) fit in? SBA, of course, provides financial, management, and procurement assistance to new and established small businesses. In terms of procurement assistance, SBA tries to make sure that small businesses get a share of the billions and billions of dollars that are spent each year by the government—from contracting to our set-aside programs. SBA's management assistance attempts to use the resources of universities and retired executives to provide training programs and counseling that might assist an industry such as drycleaning. For SBA financial assistance, most of our loans are made through the banks. The banks put up the money, and SBA guaranties up to 90 percent to $150,000. Beyond that, SBA will guaranty up to 85 percent. The limit, for the most part, is $750,000, but for pollution control facilities SBA goes up to $1 million. Some have said that $200,000 for pollution control equipment is well beyond what is affordable for many industries, and that it would take most drycleaning establishments many years to realize that kind of profit. But the SBA pollution control loan program makes money available for planning, designing, or installing a facility (see Appendix). The pollution control facility can be real or personal property that helps to prevent, reduce, abate, or control water, air, or noise pollution or contamination. Recycling programs are also eligible.

To be eligible, a small business must put together financial statements that cover two or three years, including statements for any person who has a 20 percent interest or more in the business. The applicant must also provide information on how the funds would be used and the anticipated repayment schedule. Indeed, any lender is going to want to look at repayment as the prime criterion for making the loan.

The applicant also should provide plans or specifications as appropriate for the pollution control facility and any cost estimates to ensure that the project can be completed using the loan. Additionally, applicants should provide copies of any local, state, or federal environmental regulations that relate to the proposed facility.

The advantage to a bank in making a guarantied loan is that the bank can set the terms for a longer period than for a conventional loan. Most business loans are for one to three years. But with a guaranty of the SBA, the loan can be extended to as many as 30 years. That kind of an extended payout might make such a control facility affordable. Not only is the bank able to extend the loan period with the SBA guaranty, but its exposure to loss is minimized by 10 or 15 percent, which enables banks to make loans with the SBA guaranty that they might not make otherwise on a direct basis. Thus, the SBA pollution control loan program is possibly the answer to the expense dilemma for the drycleaning industry.

Appendix. Pollution Control Loans (PCL) (Guaranty Only)

a. Program Purpose

Section 7(a) (12) of the Small Business Act authorizes SBA to provide financial assistance to eligible small business companies for the financing of the planning, design, or installation of a pollution control facility.

b. Applicant Eligibility

Applicants must meet the eligibility criteria applicable to all 7(a) loans.

Use of Proceeds

The only allowable use of proceeds are the planning, design, or installation of a pollution control facility. A pollution control facility is real or personal property which is likely to help prevent, reduce, abate, or control noise, air, or water pollution or contamination by removing, altering, disposing, or storing pollutants, contaminants, wastes, or heat and such real or personal property which will be used for the collection, treatment, storage, utilization, processing, or final disposal of solid or liquid waste. Any related "resource recovery" property (recycling) is also eligible when it is stated to be useful for pollution abatement by a local, state, or Federal environmental regulatory authority.

Loan Amounts

The maximum guaranty is $1,000,000, SBA share, less the amount outstanding of any existing SBA 7(a) exposure.

Interest Rates

Interest rates are the same as for other 7(a) guaranty loans.

Submission Requirements

In addition to general submission requirements, applicants must provide plans and/or specifications, as appropriate, for the pollution control facility and written, realistic cost estimates to assure that the project can be completed with the available sources of funds, including loan proceeds. Applicants should provide copies of any local, state, or Federal environmental regulations that relate to the proposed facility with the application.

Loan Identification

Identify Pollution Control Loans with the prefix PCL on the docket number.

Roundtable Discussion Summary: Capital Formation

Discussion about capital formation centered on clarifying the conditions of Small Business Administration-backed loans and on small business definitions and cutoff levels in the proposed EPA NESHAP regulation for perchloroethylene.

Jerry Levine of the Neighborhood Cleaners Association asked Tom Gause of the SBA to provide further information on the interest rate limits on SBA-backed loans. Mr. Gause responded that on loans for less than 7 years the banks are limited to 2.25 percent over the prime lending rate. On loans for over 7 years, the limit is 2.5 percent over prime.

John Meijer of the International Fabricare Institute asked for clarification on the difference between the pollution control loan program and the general SBA section 7A program. Tom Gause explained that the financial eligibility requirements would be the same under both programs. The primary difference is in the loan amount that would be guaranteed under the two programs. Under the 7A program, the maximum amount guaranteed is $750,000. Under the pollution control loan program, the loan guarantee is raised to $1 million.

Mr. Meijer then asked about the eligibility requirements for the loan program and whether they would differ from those faced by a lender applying for a conventional bank loan. Mr. Gause reported that the eligibility requirements would be similar, and that the bank would be looking at the borrower's ability to repay. The SBA discourages banks from rejecting loan applications for pollution control equipment based on collateral limits alone; however, SBA has no control over the lender's decision.

Tom Gause suggested that if the extent of groundwater contamination warranted it, a petition could be filed to have the situation declared a national disaster. Were this to occur, the disaster loan program could then be accessed. This program offers much lower interest rates.

Judy Schreiber of the New York State Department of Health had several comments concerning cost impacts of drycleaning exposures. She suggested, first, that drycleaners should be aware of possible liabilities associated with exposure of apartment residents and other nearby businesses that may arise. At some point, she indicated, the real estate industry will be affected by concerns over resident exposures. Finally, she suggested that health impacts of resident exposures should be included among the costs avoided under further regulation.

Margaret Round of the Northeast States for Coordinated Air Use Management asked whether the $100,000 annual receipts cutoff used to define small businesses for purposes of the EPA NESHAP regulation corresponded to a low level of emissions. Brenda Jellicorse of Research Triangle Institute and Bill Fisher of International Fabricare Institute both indicated that drycleaning emissions would be correlated with size of facility.

REGULATORY ACTIVITIES IN THE UNITED STATES

Proposed National Standards for Perchloroethylene Emissions from Drycleaning Facilities

George F. Smith
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency

Mr. Smith is an environmental engineer at EPA's Research Triangle Park facility involved with the National Emission Standards for Hazardous Pollutants that cover perchloroethylene use in the drycleaning industry. An officer in the U.S. Public Health Service, Mr. Smith's experience also includes working as a mechanical engineer in the electric power industry and as a civil engineer and construction contractor. He holds a B.S. in engineering from the University of Central Florida.

Introduction

National emission standards for hazardous air pollutants (NESHAP) covering perchloroethylene (PCE) used in drycleaning facilities were proposed in the *Federal Register* on December 9, 1991 (56 Fed. Reg. 64,382). PCE is a listed toxic air pollutant under Section 112 of the amended Clean Air Act (CAA) of 1990. The drycleaning industry emitted 83,700 megagrams (Mg), or 92,300 tons, of PCE into the air in the United States in 1991. In 1996, when compliance with the final rule is expected to take place, drycleaning facilities are expected to emit 45,300 Mg (49,900 tons) of PCE if controlled to the level of the proposed NESHAP.

Rationale for Regulation

EPA is concerned with PCE because exposure to this compound has resulted in cancer in laboratory animals. The Agency has consulted with its Science Advisory Board (SAB) on this matter. The following is SAB's view on the carcinogenicity of PCE: "It is the Committee's view that the major issues arising from the assessment of perc have not changed over the past four years, and that the SAB's previous response remains appropriate. The available scientific evidence confirms that perchloroethylene should be considered as an animal carcinogen, based on three endpoints in two species: liver tumors in male and female mice, kidney tumors in male rats, and possibly, mononuclear cell leukemia in male and female rats. Complications within each study and in their biological interpretations have made it difficult to categorize this compound. We do not consider the evidence strong enough to classify this compound as a probable human carcinogen; on the other hand, evidence for carcinogenicity is stronger than for most other compounds classified as possible human carcinogens. Therefore, in the spirit of the flexibility encouraged by the Guidelines, our best judgement places this compound on a continuum between these two categories."

Therefore, given the available evidence on the potential health effects of PCE, the Administrator has proposed, in response to a court-ordered schedule, to regulate the drycleaning industry's major and area source categories and subcategories.

The Proposed Regulation

As for all sources of air pollution in the CAA, major sources are defined as those emitting more than 10 tons per year of hazardous air pollutants (HAPs) and area sources as those that emit less than 10 tons per year of HAPs. PCE is a HAP, and 98 percent of PCE drycleaning facilities are area sources. Under the CAA of 1990, major sources are subject to regulation by maximum achievable control technology (MACT) and area sources, with few exceptions, are subject to regulation by generally available control techniques (GACT). MACT is always at least as stringent as GACT, and for the most part MACT requires state-of-the-art control of sources. GACT is determined by balancing costs and benefits. Since almost all drycleaning facilities are area sources with regard to both population and the amount of HAPs emitted, it is clear why Congress and the Administration had drycleaning facilities in mind when they passed and enacted this legislation. Drycleaning facilities are typically small businesses, and as such were given special consideration for regulation under GACT.

The proposed standard requires the use of a carbon adsorber, refrigerated condenser, or equivalent control device (95 percent control) for both major and area source dry-to-dry machines. For new, reconstructed, or uncontrolled major and area source transfer machines, the proposed standard requires the use of a refrigerated condenser or equivalent control device (85 percent control).

Pollution prevention practices, such as conducting weekly leak inspections, storing all PCE and PCE wastes in tightly sealed containers that are impervious to the PCE and do not react with the PCE, and minimizing machine door opening time, are required to control fugitive PCE emissions.

New drycleaning facilities must achieve compliance upon startup. Existing drycleaning machines that have a capacity greater than 50 lb, or 22.7 kg, must achieve compliance within 18 months of the date of promulgation (November 15, 1992). Existing drycleaning machines with a capacity of 50 lb (22.7 kg) or less must achieve compliance within 36 months of the date of promulgation.

Dry-to-dry machines consuming less than 220 gallons per year of PCE and transfer machines consuming less than 300 gallons per year are exempt from the requirements of the standard, except that operators must submit an initial consumption report to show that their operation qualifies for exemption status.

Response of the Drycleaning Industry to Recent Regulatory Activity

BILL FISHER
Vice President
International Fabricare Institute

I want to begin by making sure we understand the drycleaning industry's position on perchloroethylene (perc). Because that's really the central issue that we're talking about. We're really not talking about F113 and we're not really talking about petroleum solvent. Let's be clear about that. Our position, and the industry's position, and the position of drycleaners themselves is this: information and evidence *suggests* that perc may be a carcinogen. The International Fabricare Institute (IFI) and the industry believe that in totality the evidence most likely says that perc is probably not a human carcinogen. However, the industry also recognizes that this is not something that can be stated absolutely. And for that reason, until further scientific testing is done—something that we encourage very strongly—the industry must continue to reduce emissions and to reduce exposures. That is where we are coming from. That statement, that position, forms the basis for the actions the industry has taken.

I'd like to add one thing to that. When we are looking at the drycleaning industry, we are not dealing with General Motors. We're not dealing with some other large firm. We're not dealing with a corporate office that is located on the tenth floor of a building many miles from the production floor. We are dealing with the people that are my members. This means an owner, his or her spouse, and typically their children working in the drycleaning plant, operating the equipment, and being subjected to exposures. They are part of this. They are not absentee owners, and for that reason we owe our members the most accurate information that we can give them on science, toxicology, carcinogenicity. It would be immoral for us to act in any other fashion, and for that reason we have published information that you have never seen come out of any other industry.

We've all watched the type of stonewalling that has gone on in other cases with other chemicals. Go back and look at the information the drycleaning industry has published for its members, saying, "Here are the latest tests, these are the questions that have been raised, this is what we've got to look at. And here is the next set of tests, this is what this indicates."

The publication of such information started in the late 1970s, at a time when there was significant pressure not to make the statements that I just made. But the question is there and our industry must act responsibly. It's a position that we've taken and we have maintained for over 15 years. Our industry has tried to work with the system.

We worked very closely with U.S. EPA on the development of the original control technique guidance document for perc. That work began in the late seventies. At that time we asked the EPA's Air Office, "Are you certain that perchloroethylene is in fact a precursor to oxidant formation in the lower atmosphere? We're not atmospheric chemists, we don't have access to them, are you certain? If you're certain, we will proceed with you." The EPA's answer was: absolutely. So we worked with them. That standard was issued. We helped get it out to the states, helped ensure that there was rapid compliance in the drycleaning industry. Of course in 1981 the EPA's chief atmospheric chemist, working in EPA's own labs, found that perc is not a precursor, it does not contribute to oxidant formation. The following year, in 1982, EPA proposed a reclassification of perc to negligibly reactive. That was 10 years ago—that classification has never been finalized. I wonder why that happened?

We worked with EPA on the new source performance standard for petroleum solvent. We had our ups and downs on that. The Agency was convinced that moving to vapor absorbers for petroleum was a good course. We fought hard on that. We told them that if they were really committed to that, they needed to test it first. The Agency did, and found it was going to cost between $80,000 and $100,000 per petroleum plant to put in a carbon absorber, and instead went with an alternative standard with the industry's support.

In 1985 the Hazardous and Solid Waste Act Amendments were passed by Congress. If you look at the record you will find that the drycleaning industry is one of the few small businesses that actually supported virtually all provisions. Today approximately 80 percent of all drycleaners in the United States use hazardous waste disposal. Given the federal small-size exemption of 100 kilos, but factoring in those states that have lower or no exemptions, and melding all that together indicates that only 50 percent of the drycleaning industry needs to use hazardous waste disposal, yet 80 percent of the industry does. And I'm talking about complete waste disposal—no land disposal of any sort. Why is that figure 80 percent? I think also that if you speak to officials dealing with hazardous waste disposal at any level of government, you'll find that the drycleaning industry, in terms of its use of hazardous waste disposal, stands head and shoulders above any other small business industry in the United States.

The Clean Air Act—we've just gone through the amendments to that. Early on our industry made the decision to support that, to work with the system, to go with good, tight standards. We met with Congress and said, "These are the types of standards that have been developed, these are the types of things that EPA has been looking at; we not only support that, but we feel that the standard could be a little tighter. This is what we would envision as a standard for drycleaning—a combination of the best available control technology (BACT) and the maximum achievable control technology (MACT)—and we will support the Clean Air Act in moving forward toward a standard of that nature." That in fact is exactly what Congress did. I'll take that back. Congress, as they passed the Clean Air Act, ended up with legislative language that only requires the generally available control technology (GACT). Consistent with our position with Congress—and that was in writing—we have told the Agency, told the Air Office, that the proposal in fact, while good in many respects, should be tighter. And our official comments to the Air Office say that that standard should be tightened up.

You may find it interesting to know for those of you who are particularly familiar with the air proposal, that some seven months ago, there was a very strong push within EPA—I'm not saying within the Air Office itself, but within EPA—to raise the exemption level to $250,000 equivalent. There was also a push from another agency—I won't mention which one—to go with that $250,000 cutoff. We adamantly opposed that as unjustified and unrealistic, as a cutoff that would result in exemptions that are unacceptable. I will also tell you that as the November date last year came up, this unnamed other agency just about stopped the proposal of the perc NESHAP (National Emission Standards for Hazardous Air Pollutants). In fact, there was an article in *Inside EPA* two days ago noting—incorrectly—that no air toxics Title 3 regulations had been proposed by EPA's Air Office as a result of stoppage by this other group. And of course *Inside EPA* was wrong in that the drycleaning NESHAP had been proposed. We had to make telephone calls and send a letter saying that the standard is workable, that our industry supports it, that it is exactly in line with what Congress said was to be done under the Clean Air Act, and let's move forward.

We are concerned as an industry. We're concerned about being whipsawed. The people out there that belong to us—members that we see, customers that others here see—are concerned. Their concern is not that they want to pollute. Their concern is to do the right thing environmentally. That may be difficult in some places to believe and, let's face it, I'm not speaking for 100 percent of the people out there. There are some plants, just as there are anyplace, that are just poorly operated, where the people don't care. But across the board in this industry, that's not the case. We have people that want to do the right thing. We see a lot of cases where owners may not have been aware of a problem. And when they learn of the problem, sometimes through an inspection, they themselves are aghast, and typically move rapidly to try to correct the problem.

But where they're coming from is that this is their environment too; they want to know what to do and how they can do it without going out of business. Because to them the plain, simple economic fact is a crucial one. If doing something puts them out of business, what sense is there to any of this.

Turlock, California—we've had some discussions of the plants there. Let me lay out a little of that scenario very quickly. Take an average drycleaning plant that is grossing about $100,000 to $150,000 in sales and they have a net profit that is around 6 to 7 percent. We have an issue where you have contaminated soil on your property or you have contaminated a well. And where there may be some questions about the facts involved, tell me, how are we going to ensure, both as drycleaning industry spokespeople and as regulators, that we get to the central issue of cleaning up that contamination?

The drycleaning plant does not have the financial resources to do it. One could say, "Fine, it's going to be your problem." But the owners don't have insurance that will pay for this. You say, "Fine, let's just close them down. They were bad actors. They should have known. Let's force them to sell their assets. Let's see if we can get $100,000 or $150,000 dollars from that drycleaning plant." That's not going to work. If that drycleaning plant has that liability, there are zero assets, there is a zero worth to that plant.

We have to move forward to some solutions that will take us to cleanup. We're going to have to do it in an atmosphere that is a little more rational and reasoned, and that is a two-way street. It's a two-way street from our side and your side. We get pretty excited about being pilloried in the press. We had talks yesterday about EPA's original test-house work and the determination that garments need not be hung outside. Unfortunately, I can count at least 50 or 60 published articles that have appeared in six years citing EPA as the source—and occasionally EPA people by name—saying that the consumer should hang garments outside for 1 to 2 days after they come back from the drycleaner because of the bad health effects.

Not even a year ago there were a few news articles in the San Francisco area occasioned by a major press conference held by the Bay Area Air Quality Management District concerning the top "Dirty 30" toxic air polluters in the Bay Area. Dow Chemical's facility in the Bay Area came in lower than the 17 drycleaners who were on that list.

If we continue to go through a trial by press on issues such as this, we will not get anyplace. As an industry we want to work together, and we have a track record of doing this. But we've got to move forward, and we are at a critical time now.

Drycleaning Regulatory Activities in California

Cynthia Marvin
California Air Resources Board

Ms. Marvin is an associate air pollution specialist for the California Environmental Protection Agency's Air Resources Board. Along with leading a team of scientists and engineers in the development of a state regulation for perchloroethylene emissions from drycleaning operations, she coordinates analysis of the federal Clean Air Act's toxics provisions at the state level. Previously she led the development of California's best available control technology standards for ethylene oxide "cold" sterilization facilities. She also has contributed to development of the state's Low-Emission Vehicles and Clean Fuels Program and regulation of cooling tower emissions. Ms. Marvin holds a B.S. in environmental toxicology from the University of California at Davis.

Regulation of Air Toxics in California

In California, air toxics are regulated at two levels. The Air Resources Board (CARB) of the state's Environmental Protection Agency is responsible for developing regulations that establish the minimum requirements statewide for identified air toxics. Once control regulations are adopted by CARB, they are then adopted, implemented, and enforced by 34 local air pollution control and air quality management districts throughout the state. These districts have the primary responsibility for permitting and regulating all stationary sources. The districts may also adopt toxics regulations ahead of CARB and may adopt stricter regulations as well.

Several districts have adopted drycleaning regulations as part of their volatile organic compound (VOC) control strategy. These regulations typically require drycleaners to control their emissions by 90 percent or install a carbon adsorber that limits the concentration of perchloroethylene (perc) in the outlet air to less than 100 ppm. Many of these regulations also allow a facility to install a refrigerated condenser on a machine so long as the outlet temperature is less than 45°F (7°C). Some of the regulations prohibit the use of new transfer machines as well, and many exempt drycleaners that use less than 320 gallons of perc per year. The other way that drycleaners may be regulated in California is through new source review regulations and policies for toxics. If the source emits a compound that is on the district's toxics list—like perchloroethylene—typically all but the smallest sources must apply toxics best available control technology (BACT) and perform a risk assessment. If the estimated maximum individual risk is less than 10 in a million, the source generally receives a permit. Most new facilities applying for a permit in California generally obtain it.

The San Francisco Bay Area district is proceeding with a new toxics-based regulation for drycleaning operations. The district released a draft regulation in April that would require all drycleaners to use dry-to-dry, non-vented machines equipped with a refrigerated condenser and a drying sensor.

Based on the recommendation of the state Office of Environmental Health Hazard Assessment and our independent Scientific Review Panel, CARB identified perc as a toxic air contaminant last year. With this identification, we now are gathering and evaluating the technical information needed to develop a statewide perc regulation for drycleaners. Relevant data include: information on emissions; exposure and potential risk from drycleaning; emission reduction options, including control technology, solvent substitutes, and process changes; costs; and a detailed analysis of the potential economic and environmental impacts of regulation.

We are developing this information with the assistance of drycleaners in the state, drycleaning associations, equipment and chemical vendors and recyclers, environmental groups and concerned citizens, other state and federal regulatory agencies, and the 34 local air districts. Our goal is to develop a regulation that protects public health and minimizes impacts on drycleaners.

Survey Information*

The basis for our emission inventory is an on-going CARB survey of the drycleaning industry. The survey is a simple, two-page form, in both English and Korean, that addresses equipment type and equipment life, solvent usage, the amount of material cleaned per year, waste operations, and gross receipts. The survey also asks about residences in the building.

We mailed surveys to 5,500 potential drycleaning facilities and over 500 hotels and motels. These facilities include commercial and industrial drycleaners, linen and uniform suppliers, jails, military bases, and textile producers. Of these 6,000 surveys, about 3,000 responses have come back, as of August 1992. Of those 3,000, approximately 500 respondents are not involved in the drycleaning business at all, approximately 500 are agency shops, and about 2,000 are facilities where drycleaning is carried out onsite.

About 95 percent of the operators in this survey use perc; the other 5 percent use Stoddard solvent, CFC, and TCA. Of the perc users, more than half of the respondents use dry-to-dry, non-vented machines, most of which are equipped with a refrigerated condenser. About one-third use dry-to-dry, vented equipment and less that 10 percent of the respondents use transfer equipment.

The total pounds of clothes cleaned per year at a facility ranged from 1,500 pounds to over a million. Annual perc usage ranged from 5 gallons to 3,600 gallons. We also looked at the perc "mileage," or pounds of clothes cleaned per drum of perc. We found perc mileages of about 2,500 to 75,000 pounds per drum.

Testing for Perchloroethylene Vapor*

We have seven tests that are nearly complete, and four more scheduled. We are sampling stack or vent emissions from the drycleaning equipment or controls, emissions from the workroom exhaust vent, and the ambient concentration at a location upwind and a location downwind of the drycleaning facility. In addition, we are measuring perc in the process residue and in the separator water.

Preliminary results are not yet available; however, I can tell you about the type of equipment we are testing.

The equipment includes:

- Three transfer machines, with capacities from 30 to 70 pounds, equipped with a carbon adsorber or refrigerated condenser and using from 200 to 1,300 gallons of perc per year.
- Three dry-to-dry, vented units, with capacities from 30 to 190 pounds, equipped with a carbon adsorber or refrigerated condenser and using from 130 to 3,600 gallons of perc per year.
- Three dry-to-dry, non-vented machines, with capacities from 35 to 70 pounds, equipped with a refrigerated condenser, alone or in combination with a carbon adsorber, and using from 70 to 100 gallons of perc per year.
- Two converted, 30-pound, dry-to-dry, non-vented units, with a refrigerated condenser, and using 160 to 300 gallons of perc per year.

Our testing is based on grab sampling with analysis by gas chromatography. We are also using continuous emission monitoring at the stack and at the workroom exhaust vent. Once we have completed our preliminary technical evaluation, we will develop regulatory concepts for discussion.

Development of Regulations

We expect to consider several regulatory concepts, including a phase-out of transfer equipment; a phase-in of dry-to-dry, non-vented (close-looped) equipment; stricter requirements for new machines than for existing machines; and a tiered standard with stricter requirements for larger sources or shorter compliance times.

We are also very interested in pursuing a performance-based standard, such as a "mileage" requirement or an emission limit, that provides more flexibility and encourages pollution prevention. While developing these concepts, we will also evaluate the potential for indoor exposure and non-inhalation routes of exposure.

By legislation, the regulation that is eventually proposed by the CARB staff must be designed "to reduce emissions to the lowest level achievable through application of BACT," considering risk and cost. The regulation, of course, must be at least as stringent as the standard promulgated by the U.S. EPA.

We expect to release the results of our technical evaluation and regulatory concepts and to discuss them at a series of public workshops in September 1992. After this open discussion, we will draft a regulation and analyze the potential impacts. These materials will be published before we hold another series of workshops in early 1993. We expect to publish our final staff proposal and all supporting

*Updated in September 1992. See Appendix B, Supplemental Materials, for additional updated data.

documentation, before the CARB public hearing, in mid-1993.

Conclusion

We are currently in the midst of our technical evaluation and expect to propose a new statewide perc drycleaning operations regulation for consideration in mid-1993. If that regulation is adopted, it will then be implemented at the local level.

References

Bay Area Air Quality Management District. Proposed Rule 2-5 and Rule 8.27 (Sept. 5, 1990).

California Air Resources Board. Staff presentation for second public meeting on perc and drycleaning operations, Sept. 18, 1992. Stationary Source Division, Toxic Air Contaminant Control Branch, Los Angeles, CA.

California Health and Safety Code. Section 39002 and Sections 39660-39666.

Monterey Bay Unified Air Pollution Control District. Rule 1000 (March 19, 1986).

Sacramento Metropolitan Air Quality Management District. Rule 445-3 (Nov. 6, 1990).

San Diego County Air Pollution Control District. Rule 67.8 (Aug. 30, 1990).

San Joaquin Valley Unified Air Pollution Control District. Rule 467.1 (April 11, 1991).

South Coast Air Quality Management District. Rules 1102.1 and 1401 (Dec. 7, 1990).

Drycleaning Regulatory Activity in the Northeast

Margaret M. Round
Northeast States for Coordinated Air Use Management

Ms. Round is the toxics coordinator for Northeast States for Coordinated Air Use Management (NESCAUM). In this role she oversees the development of pollutant assessments and regional air toxics health evaluations and facilitates the review and exchange of information on air toxics risk assessments conducted by the EPA. Ms. Round also provides technical support and coordinates the activities of NESCAUM's Air Toxics Committee. She holds a B.S. in toxicology from Northeastern University.

Background on NESCAUM

Northeast States for Coordinated Air Use Management (NESCAUM) is a regional air quality planning organization that was formed in 1967 to facilitate regional evaluation of air quality problems and the development of consistent regulation to address them. The NESCAUM Board of Directors consists of the most senior state air quality officials from the six New England states and the states of New York and New Jersey.

The Air Toxics Committee was established by the NESCAUM board in 1983 to develop basic program elements related to the control of noncriteria air pollutants. In general, each member state has a representative from both its public health department and air quality division on NESCAUM committees. The reason being that the air toxic control programs in the Northeast are based on a combination of control technology requirements, acceptable ambient levels for air toxics, and residual risk assessments.

In the mid-1980s the states recognized the need to develop regional risk assessment documentation in support of regulatory decisions to control major air toxics emissions. The regional assessments reduce duplication of effort in setting air toxics standards and encourage consistency in the regulation of air toxics emissions. In addition, two other conditions existed: One was that the EPA had promulgated only seven National Emission Standards for Hazardous Air Pollutants (NESHAP), and the other was that recent knowledge in the area of health effects from exposure to air toxics provided additional methodologies for establishing health-based standards.

The Air Toxics Committee has completed regional risk assessments for tetrachloroethylene (1986), trichlorethylene (1988), and gasoline vapors (1990) that includes benzene, toluene, and xylene. The committee is currently revising its tetrachloroethylene document, a task that is expected to be completed by the end of 1992.

NESCAUM State Regulations for Drycleaners

In general, members of NESCAUM regulate drycleaning operations by requiring construction and operating permits and a demonstration that the best available control technology (BACT) is being used to minimize perchloroethylene (perc) emissions. Seven out of the eight NESCAUM states have promulgated regulations for drycleaners. The remaining state, New Hampshire, is in the process of developing regulations. A total of 22 states throughout the country have promulgated regulations to control drycleaning emissions. Common elements of these regulatory programs are:

- Refrigerated, no-vent condensers or dry-to-dry machines with activated carbon adsorption or the equivalent are considered the BACT.
- The installation of new transfer machines is prohibited.
- Ventilation standards must be complied with to minimize fugitive emissions.
- Perc discharge from drycleaning machines must be limited to 100 ppm.
- Prompt repair of leaks is required.

- The processing of contaminated waste, including reducing the residues in both the filter and in the still bottoms, is required.

- Visual inspection of hoses, tank, storage containers, and nondiffusive construction materials is carried out.

- Exemptions are made for coin-operated machines and facilities lacking space or steam capacity, hardship cases, and small sources.

Some specific elements of the state programs are worth mentioning:

- In Connecticut, emissions must be vented above the roofline from a stack with a height in keeping with good engineering practice (GEP).

- In Maine, where the state only recently promulgated its regulation, emissions at the doors and at the hood of the drycleaning machine must be exhausted at a velocity of 100 feet per minute. Additionally, Maine requires that automatic fans at the door opening vent emissions to carbon absorbers; also, spare parts must be stocked on the premise and records of maintenance and malfunctions must be kept.

- New York requires the use of carbon absorbers with a solvent vapor discharge of less than 5 ppm and nondiffusive construction material for operations near apartments, food service establishments, and nonindustrial facilities.

- In Rhode Island, drycleaning facilities that can demonstrate an acceptable ambient level of perc emissions using modeling are exempt from BACT and stack height requirements.

In general, all states that have control technology regulations incorporate pollution prevention and maintenance requirements intended to reduce the generation of emissions and waste. These include leak detection, proper storage of materials, ventilation standards, and minimization of fugitive emissions.

NESCAUM Review of EPA NESHAP

NESCAUM has reviewed the EPA's proposed maximum achievable control technology (MACT) standard for perc, and we have several pages of comments. I will highlight some of them.

EPA proposes to regulate certain drycleaning machines based on solvent consumption rate and machine size. We believe that these characteristics are not appropriate surrogates for determining perc emissions because the emissions come from several sources during the drycleaning process, including uncontrolled vents and pipes, auxiliary equipment, evaporation during the transfer and drying process, and equipment leaks.

NESCAUM also believes it is appropriate to apply MACT to all drycleaning machines for the following reasons. First, the toxicity and exposure potential of perc from drycleaning operations is extensive. Second, the economic analysis that was conducted by EPA does not account for the air quality-related health and environmental impacts. Specifically, EPA does not account for the local public health impacts for relatively high levels of exposure to perc emissions in the vicinity of drycleaning establishments. The economic impact analysis should also take into account the cost of installing control equipment, the cost savings from reduced solvent usage, and the health costs associated with exposure to uncontrolled perc emissions.

EPA modeled a population living near a plant as a basis for estimating perc reductions on a national basis. We believe this is inappropriate because the major impact of perc emissions is right in the vicinity of the drycleaning operation itself.

By not taking these factors into account, EPA limits the MACT applicability to only the largest sources. NESCAUM also recommends that performance standards and emission limits be prescribed to ensure that the control technology is working properly and that maintenance is being carried out.

Finally, NESCAUM believes that the generally available control techniques (GACT) requirement for existing transfer machines is not sufficiently justified by the economic analysis, given the potential impact of the remaining 50 percent of uncontrolled emissions from the transfer machine. Other control alternatives that are less expensive have been demonstrated for these machines, and we believe that it is necessary for EPA to revise its current proposal to take into account many of the existing control technologies that are in use, particularly in the Northeast.

Roundtable Discussion Summary: Regulatory Activities in the United States

Discussion about U.S. regulatory activities addressed the methods used to evaluate regulatory costs, the establishment of regulatory standards, and the potential impact of additional exposures on regulations currently under development.

The panel began with a comment from Walther den Otter of TNO Cleaning Techniques Research Institute concerning the costs of ground-water cleanup that had been discussed by Ross Beard of R.R. Street. Mr. Beard had indicated that it is impossible to expect a small drycleaner to come up with $50,000 to clean up perc contamination due to sewer leakages. Mr. den Otter agreed that this amount is large, but if paid for over a period of time it may be possible for the cleaner to afford the cleanup. This has been the experience in Holland. He used the example of a site where the initial survey cost $9,000 and the cleanup cost $50,000. In this case a cleanup over a period of 10 years has proved manageable.

A discussion then took place about how the savings due to regulation are balanced against the costs of compliance. Jack Lauber of the New York Department of Environmental Conservation cited an unnamed study that found a 60 percent difference in "cost per kilogram cleaned" between a state of the art drycleaner and an older transfer operation "when you incorporate solvent saving, power utility costs, and everything." This type of calculus seemed to be missing in the EPA analyses, he suggested. In response, Bill Fisher of International Fabricare Institute assured Mr. Lauber that solvent savings had been balanced against the cost of control in "every EPA economic analysis ever done on the drycleaning industry." He then explained that, while the cost of solvent saved should be examined, "supplies," which includes, for instance, solvent, bags, and hangers, represents only 4 percent of total costs in the industry; the implication being that solvent savings will only have a marginal impact on total costs. Then, Mr. Fisher discussed calculations he had done indicating it would take a drycleaner between 10 and 15 years to pay back the cost of changing over to new dry-to-dry, no-vent refrigerated equipment.

Margaret Round of the Northeast States for Coordinated Air Use Management addressed the issue of the technology specified in the federal MACT (maximum achievable control technology) standard. According to her, the technology requirements are inferior to those in place in several NESCAUM states. The MACT technology requirement for existing facilities is supposed to be that in place at the top 12 percent of the best-performing facilities.

Ms. Round stated she is not aware of a single drycleaner in the seven NESCAUM states that had gone out of business due to state requirements for controls even more stringent than the federal MACT. She gave the example of Rhode Island, where the cost of upgrading was estimated to be $4,000 to $6,000, resulting in solvent savings of approximately 50 percent. For a 5-ton per year facility the solvent savings amounted to $3,200 per year and the upgrade had a payback period of 2 to 3 years.

Bill Fisher of IFI responded that the issue with the federal MACT standard is not $4,000 to $6,000 for an add-on vapor adsorber but rather the $35,000 to $40,000 for total replacement of equipment. Mr. Fisher also responded to Ms. Round's comment concerning the appropriateness of the technology selected for the NESHAP regulation by indicating that Congress had specified that the proper technology level was GACT (generally available control technology) and not MACT.

Ms. Round then raised the issue of the perceived fairness of a federal regulation that is less stringent than existing state regulations. Understandably, the promulgation of a federal regulation with less-strict technology requirements would lead drycleaners to question the authority of the state to enforce more stringent rules.

Judy Schreiber of the New York State Department of Health argued that the small business exemption under the federal NESHAP was too liberal. According to her, half of the drycleaning shops in New York City would be exempted. Given her findings concerning exposures of apartment residents, this exemption is "unconscionable." There is no evidence that smaller, exempted cleaners have a lesser impact on apartments than larger ones.

Dr. Schreiber then asked George Smith of EPA's Office of Air Quality Planning and Standards whether these findings would influence the future direction of the NESHAP. Mr. Smith indicated that EPA had received copies of the New York State comments and that they were considered "very serious" comments.

Dr. Schreiber asked Bill Fisher for an opinion on the significance of these findings on the direction of the NESHAP regulation. Mr. Fisher responded that, first, the level of exemption included in the NESHAP was indeed a concern to the industry and that IFI had supported a lowering of the small business cutoff number. Second, in regard to the potential future direction of the NESHAP, Mr. Fisher expressed a personal opinion that EPA would be on "very shaky legal ground" to address indoor air concerns under the Clean Air Act Amendments.

A final question came from Elizabeth Bourque of the Massachusetts Department of Public Health concerning whether any of the states had looked at, or had plans to look at, the number of drycleaners that are adjacent to food stores or restaurants. Bill Seitz of the Neighborhood Cleaners Association responded that they are taking a look at this issue.

INFORMATION DISSEMINATION

Communicating about Environmental Risks Related to the Drycleaning Industry

Caron Chess
Environmental Communication Research Program
Rutgers University/Cook College

Ms. Chess is director of the Environmental Communication Research Program at Rutgers University. The focus of the program is to conduct research and provide consulting services and training to industry, government, and nonprofit organizations on effective communication of environmental health issues. Ms. Chess is coauthor of a book and author of numerous articles on risk communication. Previously she coordinated the New Jersey Department of Environmental Protection's implementation of a Right to Know law, which gave the public access to information about toxic substances.

A number of years ago I learned what those outside the risk communication field thought about the evolving field of risk communication when I got a call from a trade association asking me to be the after-dinner speaker at its annual meeting. It seems the organizers of the dinner usually got a magician for that slot, but he couldn't make it this particular year. So they turned to me.

I find that people still want the abracadabra approach to risk communication. That is, they are looking for some magic words that will soothe all of those unduly alarmed and wake up all of those unduly apathetic.

Of course, those magic words don't exist for the issue that is the focus of this roundtable, or for any other environmental issue that I've dealt with. Risk communication—like pollution prevention or good science—requires research, planning, and evaluation. I have not done original research on risk communication in the drycleaning industry, and to my knowledge no other researchers have focused on this area. So what I will do in this presentation is review some of the false assumptions that people in government and industry tend to make about risk communication, summarize the realities as they have applied to other risk communication issues, and then raise some concluding questions.

First myth: When explaining risk, sound more certain than you are.

Reality: When government officials or industry representatives yield to the pressure to sound more certain than they are, they become vulnerable to charges of inaccuracy at best or cover-up at worst. Learning to acknowledge uncertainty on environmental risks may be one of the toughest risk communication lessons, but it also may be one of the most important for controversies like those that have been swirling about at this roundtable.

Am I suggesting that in response to relevant questions that you shrug your shoulders and say, "Darned if I know?" Absolutely not. But I do suggest that you (1) say what you do know, (2) indicate the bounds of your certainty, (3) state what has been done to reduce the uncertainty, and (4) announce what will be done to reduce it further.

Let's take an example from the materials I've read on the drycleaning industry. Before I read this statement, I should say that I am not going to debate its accuracy; I know that would be out of bounds for this forum. I want you to listen to the statement and think about whether you think it enhances readers' trust in the drycleaning industry. This is the quote, taken from a letter to the editor written by the head of a drycleaning association: "The best evidence that exists is that mice and rats sometimes contract cancer, but there is no evidence that there is any danger to people."

Now we don't have any research on this, but the assumption that I've often heard from people in the drycleaning industry is that acknowledging uncertainty and being forthright about the controversial issues is only going to alarm people. My hypothesis, instead, is that this statement leads to an industry spokesperson sounding defensive, rather than sounding like someone interested in telling people the entire truth. I suspect that such a statement might lead readers to think that the drycleaning industry is more concerned about deflecting blame than solving problems. Having participated in this roundtable, I don't think that's the case in the drycleaning industry, and I don't think that's the impression that spokespeople for the drycleaning industry want to convey. So the questions that you should ask are, How can you give people an understanding of the apparent environmental risks? and, How can you assess the affect of that information on consumers and people living near drycleaning facilities, as well as on people who work in the industry?

Second myth: When preparing presentations or materials for the public, focus on what you think is important.

Reality: What you think is important and what your audience considers important may be quite different. I often suggest to people in workshop groups that they should develop materials—and this includes materials for people in the regulated community as well as consumers—that answer three questions.

- What do I want to get across? (The question most presenters ask themselves.)
- What does my audience want to know? (The question presenters tend to leave out.)
- What is my audience likely to get wrong if I don't correct the misconceptions ahead of time? (The question most presenters never consider.)

The materials that I was sent in advance of this gathering include some very useful information. Yet some bottom-line issues are not adequately addressed. Consider the kinds of questions that might be asked by people living near a drycleaning establishment. Such as, "How do I know if I should be concerned?" "How do I find out what I can do?" "And what are you—drycleaning industry leaders and government officials—doing to protect my health?"

The kinds of questions that consumers might ask include: "How do I know if I have a good drycleaner?" That is, not just a drycleaner who can get my white silk shirt clean, but a good drycleaner in the environmental sense?

I was very pleased to find some guidance in regard to such questions from one of the drycleaning trade associations in the roundtable advance materials. Again, I don't know whether the guidance is sound, but I was pleased nonetheless that information is being provided for consumers so that they can begin to distinguish between "responsible" drycleaners and those whom they should be concerned about. One trade association suggestion is for consumers to look for notification at the drycleaning shop indicating membership in a professional association. The second is to use your nose when you go into a drycleaning establishment. And the third is to use your nose when you take your clothes home. What I understood from this is that if things smell bad, it might indicate that the cleaner is somewhat less than environmentally responsible.

Third myth: Disclosing data is likely to alarm people.

Reality: Withholding data is likely to cause people to question you and everything you stand for. In the face of the uncertainty about many drycleaning issues, it would be tempting to say, "Let's wait to communicate with the public, until we know exactly what is going on and what we are going to do about it." I commend the roundtable organizers for putting communication on the agenda, and I urge participants to take a lesson from the chemical manufacturing industry. A 1990 public opinion poll gave the industry a 27 percent approval rating, which was next to the lowest, above only the tobacco industry. Many leaders in the chemical industry now acknowledge that they hid for too long behind the factory gates and that withholding information, even when it was with the best of intentions, led to an erosion of the public trust.

I suspect—although I have no data on this issue—that neighborhood drycleaners are accorded a fair amount of trust from their customers and are seen as a fixture in the neighborhood. In the suburbs, the drycleaner's shop may be one of the few commercial establishments where somebody knows your name. That trust is the industry's capital to invest or squander. If you are not the source of the information, someone else will be, and then the question will be, "Why didn't you tell us?"

Fourth myth: Risk communication can wait until we've dealt with the substantive issues.

Reality: The result of this type of thinking is that resource-intensive attempts must be undertaken to put out communication fires, which might have been averted with effective planning. It does not work to do years of study on an issue and then hurriedly plan the communication effort, particularly on an issue like this that involves so many people and such diverse audiences, including small business owners (who may only know English as their second language), consumers, and neighborhood residents. I would urge that when you conduct or are involved in epidemiological studies, that communication with subjects before, during, and after the study be designed into the plan. Monitoring studies need to deal with the businesses involved and the people potentially exposed.

In conclusion, I've heard your concerns about communicating to the public regarding the potential risks of drycleaning operations. Implicit in those concerns is a lot of fear about how the public will respond. It is important for industry and agency officials to examine their fears about the public and how those fears are influencing how they deal or don't deal with the communication of risk. I ask finally: Are you planning to communicate to the public? And if not, Are you dooming yourself to failure regardless of your technical expertise or your policy development efforts?

Appendix

The following figure was submitted for the roundtable by Ms. Chess but not referred to specifically in her presentation.

LADDER of CITIZEN PARTICIPATION

Citizen Power	Citizens act without communicating with government	• volunteer fire department; • citizen investigation; • citizen development and implementation of programs
Power-Sharing	Citizens and government solve problems together	• funding of citizen groups to hire technical consultants and/or implement projects; • citizen oversight and monitoring; • meetings called jointly by government and citizen groups
Consult 2	Government asks citizens for meaningful input and intends to listen	• citizen advisory committees; • informal meetings; • on-going dialogue; • some public hearings
Consult 1	Government asks citizens for limited input and would prefer not to listen	• most public hearings; • most requests for responses to formal proposals; • pro-forma meetings and advisory committees
Inform	Government talks; citizens listen	• some public meetings; • press releases and other informational strategies: newsletters, brochures, etc.
Government Power	Government acts without communicating with citizens	• some investigations; • legal and enforcement actions

The Drycleaning Industry's Perspective on Risk Communication

William Seitz
Neighborhood Cleaners Association

Bill Seitz is the executive director of the Neighborhood Cleaners Association (NCA), which has 4,000 members in nine states. Mr. Seitz began his 47 years in the drycleaning industry as a journeyman learning the different phases of the business. He has been with the NCA since 1949, working as a garment analyst, field representative, and instructor. He is a consultant to the Metropolitan Museum of Art in New York and to the Textile Conservation Workshop. Mr. Seitz is a graduate of the Straubenmueller School of Textiles and the National Institute of Drycleaning.

The question of the drycleaning operator's perspective on information dissemination and/or risk communications is really a much broader subject than it would seem. The reality is that there are actually four distinct areas of information dissemination that affect the operator and they vary substantially as to the impact they can have on the particular business.

The four areas are:

- Intra-industry
- Drycleaning operator to customer
- Governmental agency to drycleaning operator
- Governmental agency to the drycleaning operator's customers

Intra-industry

To understand and appreciate why the drycleaning industry has progressed as rapidly as it has in accepting and complying with government regulations, look to the work of the trade associations, allied trade firms, and the drycleaning trade press. From the very inception of the regulatory process, the trade associations have been in the forefront of this important and positive program. Areas of activity have included analyzing regulations, disseminating information, and assisting in getting the operators to comply. Trade associations have acted as a conduit for various governmental agencies in order to bring the industry into compliance—from hazardous waste "milk-run" pickup programs to inspecting operators' plants or giving operators the tools for self-inspection. Trade associations have held hundreds of seminars, meetings, and workshops to educate operators. The associations and the industry press have written regularly and often on the subject of compliance and the need for the operator to act in a responsible manner in regard to the business and the community. Rather than positioning themselves as adversaries of the government and the regulatory process, the trade associations have been a positive and powerful force in working with the various federal, regional, state, county, and city agencies.

Drycleaning machinery manufacturers have developed technology that has substantially improved the performance of equipment, whether through facilitating retrofits for existing equipment or continuing to develop the state of the art in drycleaning technology. Solvent manufacturers have participated in the process by developing technical information and procedures regarding the safe handling of perchloroethylene (perc).

Obviously these efforts should be continued, although in a closer working relationship with EPA and the various other agencies that interact with the drycleaning industry.

Drycleaning Operator to Customer

This is a relatively new area of risk communications where the operator and the industry need assistance and expertise. What the operator needs to do and wants to do is to explain the drycleaning operation and the areas of potential risk. The operator wants the customer and the community to understand the efforts being made and the precautions and safety measures being taken, without creating unnecessary concern, and more importantly, fear and rejection of the drycleaning service. Perc has a history of almost 60 years of safe use in the drycleaning industry, usually in residential and retail shopping areas, without any serious hazards or repercussions. What the drycleaner wants to do is to continue to improve where possible and to maintain credibility and customer goodwill in the community.

The drycleaning operator also needs the cooperation of the various governmental agencies, especially in regard to how the general media is reporting on the industry.

Governmental Agency to the Drycleaning Operator

Given the history of cooperation between the industry and governmental agencies, the drycleaning operator would hope for a reasonable and cooperative attitude on the part of the governmental agencies that interact with the drycleaning industry.

Permits and Fees

There have been steady increases in the rate of various fees for licenses, permits, and compliance services. In some cases, these fees are duplications, for example, a county requiring the same permit or license already being paid to the state. In many cases the fees have been increased to the point of being unreasonable, as in New Jersey where the fee for a routine inspection of a drycleaning establishment has been increased to $1,330. If the inspector deems it necessary to return to the establishment, an additional $700 is charged. Previously, the charge for this inspection was $500.

Penalties for Violations

Neither warnings or a sufficient opportunity to comply with even minor infractions of EPA or Occupational Safety and Health Administration (OSHA) regulations are provided for drycleaning operators. And the penalty for some of these infractions are excessive—$1,000 to $2,000 per violation in some cases.

Governmental Agency to the Drycleaning Operator's Customers

Drycleaning operators generally agree that there is absolutely no question but that the public must be informed about risk or potential risk to which individual may be subject. The important question is, How should this be handled and controlled when the governmental agencies report to the media. The various relevant governmental agencies include: EPA and its divisions, such as the Cancer Advisory Group (CAG); the Consumer Product Safety Commission (CPSC); the Office of Toxic Substances (OTS); OSHA; the various state and city health departments; and the various air and water boards and departments throughout the country.

These agencies have a dual responsibility. While they must report risk to the public and the media, they also have a responsibility to report fairly and objectively. Along with the responsibility they have to the public, agencies also have a responsibility to the drycleaning operator and that operator's business. Too often, comments made by officials of various agencies have resulted in consumer hysteria and overkill of a problem or potential problem. [As examples of exaggerated reporting by the media, Mr. Seitz cited a recent article in the *Village Voice* and showed videotapes of a two-part news report aired by the New York City CBS-TV affiliate. Mr. Seitz said that some drycleaning business was lost as a result of these reports.] Often, the result has been a loss of business and credibility in the community for the drycleaning operator.

Conclusion

The need for risk communication and information dissemination is a growing need that must be addressed. What is said and how it is said becomes ever more important as the public is subjected to information that is deemed important. The drycleaning operator is anxious to participate in the process, but is concerned about what will be considered the best way to disseminate the information. In particular, the operator is concerned about how the various governmental agencies will present the information to the industry and to the general public.

Communication of Risk Associated with Drycleaning Operations in New York State

Judy S. Schreiber, Ph.D.

Bureau of Toxic Substance Assessment
New York State Department of Health

Dr. Schreiber is a senior research scientist at the New York State Department of Health with extensive experience in assessing human exposure and health risks related to chemicals. She is actively involved in efforts to improve the indoor air quality in buildings where drycleaning establishments are located. Dr. Schreiber holds a doctorate in environmental health and toxicology from the State University of New York's School of Public Health.

As a result of the study the New York State Department of Health conducted in Albany confirming suspicions about the high level of tetrachloroethene levels in apartments located above drycleaning operations (see earlier presentation), the Bureau of Toxic Substance Assessment began an outreach program to identify what we consider "high-risk" drycleaning facilities and to assess the impact these operations have on residential areas.

We believe that the levels found in these apartments confirmed a previously unrecognized, very high magnitude exposure for people living near drycleaning establishments. We found residential exposure levels that are orders of magnitude higher than a person would be subject to, for example, living in the proximity of a hazardous waste site.

I have a lot of experience in different areas of environmental health, and, in all candor, these exposure levels are really of a much higher magnitude than I have seen in any other environmental area, including exposure related to contaminated water supplies, hazardous waste sites, and pesticides. If you compare residential exposures from drycleaning establishments to what one would be exposed to living on the same block as a Superfund hazardous waste site, I doubt you would find any exposures that would come close.

The outreach program that we undertook has been very successful, and we had a great deal of cooperation from the Neighborhood Cleaners Association (NCA). The NCA let us use their membership list to send out our survey requesting information about the proximity of businesses to residences. The list comprises about 3,100 drycleaning businesses located throughout New York State. The NCA went further still by sending a letter to members as well as nonmember drycleaners about a week before we mailed our survey, encouraging cooperation so that we could get a better sense of where the problem drycleaners are located.

Figure 1 shows the survey, which was accompanied by a cover letter explaining some of the results from the Albany study indicating that there are high emission levels associated with apartments located in buildings with drycleaning establishments.

We designed the survey so that it would be very easy to fill out. Rather than asking for exact numbers, we used a checkoff system that is set up on a data base at the State Health Department offices in Albany.

New York State Department of Health
Bureau of Toxic Substance Assessment

DRY CLEANER SURVEY

Name of Establishment: __________

Address of Establishment: __________

__________ (County)

Telephone Number: (____) __________

Name of Proprietor: __________

PLEASE CHECK THE APPROPRIATE BOX REGARDING YOUR OPERATION.

1. Solvent Used: ☐ PERC (perchloroethylene) ☐ Petroleum (Stoddard) Solvent ☐ Fluorocarbon ☐ Other

   Approximate number of gallons used annually: __________

2. Machine Type: ☐ Transfer ☐ Dry-to-Dry (vented) ☐ Dry-to-Dry (no vent) ☐ Other
3. Pounds of Garment Dry Cleaned each Week (maximum): ☐ Less than 1,000 pounds ☐ 1,000 to 2,000 pounds ☐ Greater than 2,000 pounds
4. Other Uses of Building besides Dry Cleaner: ☐ Residential ☐ Other Business ☐ Other
5. Distance to Nearest Building: ☐ Less than 50 Feet ☐ 50 to 100 Feet ☐ Greater than 100 Feet
6. Source of Water Supply for Dry Cleaner: ☐ Public ☐ Private
7. Sewage System for Dry Cleaner: ☐ Public ☐ Private

Signature of Preparer: __________

Name of Preparer: __________

Date: __________

DOH-3481 (1/92)

Figure 1. Survey form used to solicit information from drycleaning operators in New York State.

We have gotten a high rate of response for a survey of this type, considering there is no legal requirement for participation. I think the NCA contributed significantly to the success of the survey by encouraging members to cooperate. Out of the 3,100 surveys that were sent out, to date we have gotten back over 1,700, which is a greater than 50 percent response rate. At the beginning, I would have been surprised if we obtained a response rate of 10 or 20 percent.

The program in New York State has been quick to identify establishments that pose the greatest risk to the public. The Albany study was conducted in the summer of 1991. Since that time we have analyzed the results, published a report, initiated our survey, and have gotten a fair idea of the location of the "high-risk" drycleaning operations.

The distribution of drycleaning operations covered by our survey is close to evenly split between New York City and the rest of the state, which is in keeping with our earlier estimates (Table 1). There may be a slightly higher percentage in New York City. It should be pointed out that we do not know the population of nonresponders, and there could be a bias in the responses that we have, compared to the actual distribution.

Table 1. Summary of preliminary results of New York State drycleaning operations survey (as of May 1, 1992).

Location	Total # Responses	Total # Residential	Total # Business	Other or No Use	Dropstore, Out of Business
Bronx	138	29 (21%)	93 (67%)	11 (8%)	5 (4%)
Kings (Brooklyn)	231	111 (48%)	82 (36%)	28 (12%)	10 (4%)
New York	218	113 (52%)	69 (32%)	8 (4%)	28 (13%)
Queens	251	57 (23%)	159 (63%)	26 (10%)	9 (4%)
Richmond	44	5 (11%)	25 (57%)	10 (23%)	4 (9%)
Total NYC	882	315 (36%)	428 (49%)	83 (9%)	56 (6%)
Total Statewide, excluding NYC	883	66 (7%)	505 (57%)	232 (26%)	80 (9%)
Grand Total	1765	381 (22%)	933 (53%)	315 (18%)	136 (8%)

Note: Percentages indicate portion of total response.
Source: New York State Department of Health, Bureau of Toxic Substance Assessment.

In New York City, 315 of 882 drycleaners who responded are located in buildings with residences—about 36 percent. The total number of drycleaning establishments located in buildings where there are other businesses (including offices, schools, and restaurants) is close to 50 percent. Thus, the combined residential and business exposures related to these New York City operations is about 85 percent. When we began planning the survey, we assumed that 85 to 90 percent of New York City drycleaners are operating out of buildings that also house either other businesses or residences.

The "Other or No Use" column lists data that includes respondents for whom it was unclear from the survey information what the drycleaner intended to indicate and respondents that operate where there is no other use of the building (about 9 percent of the respondents).

The last column—"Dropstore, Out of Business"—lists the number of respondents who indicated that there is no active drycleaning operation on the premises (i.e., distribution-point shops) or that drycleaning services are no longer offered at that location.

Outside of New York City, the distribution of drycleaning establishments is quite different. Although we surveyed about the same number of drycleaners, we found that only about 7 percent of respondents operate in the proximity of residences. Some 57 percent of respondents, however, are located in buildings that also house other businesses. A large portion of these operations are located in small malls where they tend to be next to other service-type businesses. In many cases, we find that these operations do have problems with air quality because often small malls have a single ventilation and circulation system, which distributes emissions from the drycleaning shop throughout the mall enclosure. We are particularly concerned about exposures in situations where a drycleaning shop is near a restaurant or other food service establishment, since, as we heard in Dr. Diachenko's presentation, Food and Drug Administration studies found that butter and margarine absorb perchloroethylene (perc).

About 30 percent of survey respondents in New York City operate transfer drycleaning equipment in buildings with other businesses (Table 2). The percentage of New York City respondents operating transfer machines in the proximity of residences is about the same, approximately 33 percent (Table 3). A somewhat smaller percentage statewide, ranging from 20 to 35 percent, use transfer machines in buildings with residences or other businesses.

Table 2. Preliminary results of New York State drycleaning operations survey: Drycleaning establishments located in a building with other businesses (as of May 1, 1992).

Location	Total # of Dry Cleaners in Bldgs. with Businesses	MACHINE TYPE		
		Transfer	Dry-to-Dry Vented	Dry-to-Dry Non-vented
Bronx	93	31 (33%)	28 (30%)	34 (37%)
Kings (Brooklyn)	82	29 (35%)	17 (21%)	36 (44%)
New York	69	11 (16%)	14 (20%)	43 (62%)
Queens	159	54 (34%)	38 (24%)	67 (42%)
Richmond	25	2 (8%)	7 (28%)	16 (64%)
Total NYC	428	127 (30%)	104 (24%)	196 (46%)
Total Statewide, excluding NYC	505	100 (20%)	130 (26%)	275 (54%)
Grand Total	933	227 (24%)	234 (25%)	471 (50%)

Note: Percentages indicate portion of total response.
Source: New York State Department of Health, Bureau of Toxic Substance Assessment.

We consider drycleaning establishments operating transfer machines in the same building with residences to be our highest priority. The State Health Department

Table 3. Preliminary results of New York State drycleaning operations survey: Drycleaning establishments located in residential buildings (as of May 1, 1992).

Location	Total # of Dry Cleaners in Residential Bldgs.	MACHINE TYPE		
		Transfer	Dry-to-Dry Vented	Dry-to-Dry Non-vented
Bronx	29	14 (48%)	8 (28%)	7 (24%)
Kings (Brooklyn)	111	39 (35%)	19 (17%)	52 (47%)
New York	113	31 (27%)	15 (13%)	67 (59%)
Queens	57	20 (35%)	14 (25%)	22 (39%)
Richmond	5	1 (20%)	1 (20%)	3 (60%)
Total NYC	315	105 (33%)	57 (18%)	151 (48%)
Total Statewide, excluding NYC	66	23 (35%)	14 (21%)	29 (44%)
Grand Total	381	128 (34%)	71 (19%)	180 (47%)

Note: Percentages indicate portion of total response.
Source: New York State Department of Health, Bureau of Toxic Substance Assessment.

has asked New York county and district health departments to visit the high-priority facilities within their jurisdictions and, with the cooperation of the State Environment Conservation Department, to inspect the drycleaning equipment, take air measurements with a photoionization detector (PID) or a similar device in the apartment and common areas of the building, and make a preliminary assessment of emission levels. I am pleased to report that we have had considerable success working with the county health departments and the Environmental Conservation Regional Office in this effort. Unfortunately, at drycleaning establishments of this type we almost always find an air-quality problem in residences within the building.

We are conducting an outreach program and are working with the NCA and other industry groups to help drycleaners improve their emission controls and ventilation so that the impact on these residents is reduced. Our intention is not to put drycleaners out of business, but to help them become better neighbors. We are trying to work with them to help them design improved ventilation and emission control strategies. This is really a very new area, and we don't have the answer in every situation, since each building, drycleaning operation, and ventilation system is different. Unfortunately, it takes intensive staff work and a lot of time to visit these facilities, evaluate the equipment, assess the emissions into residences (e.g., look for pipe chases and stairwells and chimney effects that tend to distribute solvent vapor throughout a building), and make recommendations to remediate the facility.

Soon we will be sending a followup to all of the drycleaners who did not respond to our initial mailing. Also, we now have a more comprehensive list of drycleaning facilities in the state and will be sending out another 2,000 surveys. We currently estimate that there are close to 3,700 drycleaners operating in New York State.

Based on preliminary survey results, about half of the drycleaners in New York State would be exempted from regulations proposed in the Clean Air Act Amendments, based on usage of perc. We believe that the amendments as they would apply to emissions from drycleaning operations are inadequate. A facility does not have to be a very large consumer of solvent to have an extensive local impact on air quality. Indeed, in the Albany study, at least four out of six drycleaning establishments would be exempted under the regulations proposed for drycleaners. Yet clearly many had a substantial impact on the air quality of residences sharing the building.

We also developed, as part of our outreach program, a fact sheet for our county health departments to send to residents who have questions about drycleaning operations and their impact (see Appendix B). It is written in nontechnical language, and we tried our best to be forthright with the information, to give the test results as we know them, and to be as honest as we could about the health effects we believe are related to solvent exposure. We try to stress that many of these health effects result from chronic exposure over a very long period of time, and that if one learns about an exposure today, he or she is not going to die from it tomorrow. We advocate that every effort be made to improve the air quality near drycleaning establishments.

The New York State Health Department has developed numbers on the potentially exposed population; estimates that were initially based on various assumptions and then updated with the actual survey results. We estimate that 150,000 to 200,000 people in the general population of New York State are being exposed to elevated levels of solvent vapor as a result of their proximity to drycleaning establishments. That's quite a few people, and we think EPA should address questions about residential and business exposure. It should also address the exposure of people working at business establishments that are in the vicinity of drycleaning establishments.

We still need some type of monitoring device that would provide a reliable and inexpensive means of measuring solvent vapor levels in the air of residences. At the State Health Department, we are attempting to modify current-technology monitoring badges (made by 3M and other companies) so that they can be used to measure levels of solvent vapor in residences. Such a device would minimize the time it takes our staff to set up a four-hour (Porapak) pump or a twelve-hour evacuated canister system that requires a technician to set up the system, return to dismantle it, and then send the samples to Albany. We need a device to accurately measure tetrachloroethene at low levels. Such a device would save us a considerable amount of time in assessing air quality. Possibly EPA could look into the development of a monitoring device that meets these criteria.

Roundtable Discussion Summary: Information Dissemination

Discussion about information dissemination focused on the media coverage of environmental issues (including drycleaning), and on the industry's approach to dealing with information dissemination. The ownership of drycleaning establishments by members of ethnic groups who may not speak English as their first language was also discussed.

The discussion began with an exchange concerning the differences between transfer and dry-to-dry machines in terms of their emissions problems. George Smith of EPA's Office of Air Quality Planning and Standards asked Bill Seitz of the Neighborhood Cleaners Association and Judy Schreiber of the New York State Department of Health to discuss whether they feel transfer machines are necessarily worse than dry-to-dry and if so, why.

Bill Seitz explained that in the transfer process, solvent-laden garments are physically transferred to a separate reclaimer unit. During this transfer there is a release of solvent vapors from the cage of the machine and the garments. In the dry-to-dry operation, washing and reclaiming operations take place in a single closed unit. If run properly, the garments come out dry with only a small residual of perc left in them.

Dr. Schreiber felt that the problem is not so much in the type of machine but in the way that it is operated. A poorly operated dry-to-dry machine can be as problematic as a transfer machine. She added, however, that she has yet to see a properly operated transfer machine.

Bill Seitz noted that of the nine drycleaners shut down by New York State over concern for apartment resident exposures, five were operating so-called state-of-the-art closed-loop dry-to-dry machines. Of the four transfer operations that had to close, two were allowed to reopen after performing the necessary maintenance and repairs. If properly maintained, then, older transfer equipment can operate safely and effectively, he suggested.

Jack Lauber of the New York State Department of Environmental Conservation added that a problem with transfer operations is that clothes may be removed before they are sufficiently dried. Cleaners may reduce the residence time in the reclaimer unit to achieve greater production. Also, with older transfer machines, he added, it can be difficult to obtain replacement parts.

Ken Adamson of the Ontario Drycleaners and Launderers Institute suggested that few transfer machines anywhere are likely to be operating at maximum efficiency simply due to the age of the equipment. He indicated that it is much easier to achieve low emissions with state-of-the-art dry-to-dry equipment. Nevertheless, some operators of new dry-to-dry equipment may shorten the drying cycle to obtain a higher rate of cleaning throughput.

The discussion then turned to the question of communication with facility operators concerning operational and environmental issues. Ross Beard of R.R. Street spoke first and addressed the fact that many owners do not speak English as their first language. He estimates that perhaps 25 percent of facilities nationwide are owned and operated by Koreans. In New York City, he claims, the figure is probably higher and may be increasing. Dr. Schreiber responded that the regulatory officials in New York, at least, are aware of this. Her office has been in touch with the Korean Drycleaners Association, and she will be attending one of their meetings shortly to explain the survey that is being conducted to assist in the evaluation of apartment resident exposures.

Cynthia Marvin of the California Air Resources Board estimated that about half of the drycleaners in California are owned and operated by Koreans. Due to the language barrier that may exist for these operators, state officials are considering preparing a compliance assistance program manual that would use simple "comic book" style diagrams to explain regulations and proper operating procedures.

Elden Dickenson of the Michigan Department of Public Health added that about 25 percent of facilities in that state are Korean-owned and operated.

Attention then turned to the video clip shown by Bill Seitz of a CBS News report on the hazards associated with drycleaning. Lynn Luderer of EPA asked Caron Chess of Rutgers University for her reaction to this particular piece of media reporting. Ms. Chess began by observing that it appeared to be the assumption of most industry participants that the public's reaction to the news report would be one of hysteria. Her own reaction, however, was that there may be some reason for concern, particularly for those living above drycleaners, yet she said she did not get the impression that she should immediately stop taking her clothes to the cleaners. Industry in general seems to believe that providing information is dangerous. Her experience with industry communication issues, though, is that public reaction is at its worst when it appears that industry may have had information concerning a problem but either dismissed the problem or failed to reveal the information. When this happens, she feels, industry is perceived as being "uncaring" and "callous." This impression is one that they likely do not wish to convey, she suggested.

Dr. Schreiber agreed that the actual reaction provoked by the CBS report was much less than the state officials expected. A total of 50 to 70 calls were received at the telephone number broadcast with the report, whereas they were anticipating the possibiliy of hundreds of calls. Most of those who called were people living above drycleaners, not drycleaning customers. In a city of 11 million, this seemed to her to be a very small number of calls. John Meijer of the International Fabricare Institute responded that 70 calls did seem like a lot. Most consumers, he suggested, do not complain, they just don't come back.

Several participants from the New York area (Jerry Levine, Margaret Round, Bill Seitz) gave testimonials as to the general sensationalist nature of the New York media. Jerry Levine of NCA described how the CBS reporter had been taken through a state-of-the-art facility to see an operator that was running a good shop. Nothing from that visit, however, was ever shown in the broadcast.

Elden Dickenson provided another anecdotal example of inaccurate reporting that hurts the drycleaning industry. An article appearing in one of the Detroit papers recommended that customers ask their drycleaner when they change their solvent, because that was the best time to get clothes cleaned. In reality, drycleaners do not "change" solvent. They are constantly purifying, recycling, and reusing it.

Scott Lutz of the Bay Area Air Quality Management District then addressed the reporting that had surrounded the district's release of a list of facilities that had been evaluated using the risk assessment methodology required under the Hot Spots Information Act, a right-to-know law enacted recently in California. State officials held a public meeting to discuss the methodology, the results, and the uncertainties associated with the methodology. Much of the reporting on the meeting was balanced and non-alarmist in nature. One paper, which happened to be in some financial difficulty, had decided to sensationalize the issue. It reported the results under the heading of "Top Dirty Thirty"; the dirtiest 30 facilities in the Bay Area. Of these 30 facilities, 17 were drycleaners. Naturally the industry resented what it felt was an irresponsible use of the state's analysis to create a scare concerning drycleaners that may not have been warranted.

Faye Dworkin of the Consumer Product Safety Commission suggested that the industry work with her office on a joint communication project for consumers. Bill Seitz accepted her offer of assistance and indicated that NCA would be happy to work with CPSC.

ROUNDTABLE WRAP-UP

Roundtable Wrap-Up: Discussion Summary

The wrap-up discussion session provided an opportunity for participants at the roundtable to generate ideas to address exposure issues related to drycleaning and to consider options for follow-up to the roundtable.

The session was organized into three parts. The first task was to develop a list of *issues* that had been raised, or that participants otherwise felt should be addressed in follow-up activities. The group then spent time developing a list of *ideas*, or ways to address these issues. Finally, time was allowed for discussion of potential follow-up activities by EPA.

The bulleted items below represent the issues or ideas raised during the wrapup session discussion. The originator of each issue or idea is identified in parentheses (refer to Appendix A, Attendee List, for full name and affiliation).

Issues

- Epidemiological study (Ruder)
  - National Institute of Occupational Safety and Health is looking for population to study
- Compendium of risk assessments (Round)
- Total exposure assessment (Schreiber)
  - focus on local effects
  - foods, fats, water, air
- Solutions for indoor air problems (Seitz)
- Contact-water disposal through presently available technologies (Seitz)
- Real estate issue
  - land use as affected by drycleaners
- Industry *not* an adversary, but a partner in solutions (Seitz)
- Exposure (Bourque)
  - cooperation
  - benefits to industry
- Future technologies and regulations (Dworkin)
- Residual perc in clothing needs more study (Adamson)
  - also in building materials (Schreiber)
- Regulatory coordination—federal, state (Meijer)
- Training and certification for drycleaners; Canada's environmental code of practice (Portugais)
- Sharing of communication materials among agencies, governments (Portugais)

Ideas

- Form an industry advisory group (Fisher)
  - joint industry/government advisory group (Bourque)
- Gather information on exposure levels associated with different types of machines (Bourque)

- Perc emission controls encouraged with tax on perc (Phillips)
- Develop communication strategy by both government and industry
  - should be done separately to enhance credibility of each (Chess)
- Conduct research on risk communication (Chess)
  - effectiveness, target audiences
- Develop funding mechanism for cleanup, especially for ground water (Cohen)
- Devise alternative incentives for cooperation (Dworkin)
  - example: certification program
- Develop ventilation standards (Lauber)
  - What are good standards?
- Involve key environmental organizations in risk communication effort (Lauber)
- Consider whether drycleaners should be located next to homes, food establishments, and other businesses (Bourque)
- Develop communication program for drycleaners (Chess)
  - recommend to association members that they avoid locating in residential areas or next to stores, if possible
- Encourage use of pollution prevention to further reduce emissions (Round)
- Develop methods for enforcement of more flexible regulatory approaches that can increase compliance (Marvin)
- Communicate with local and municipal governments (Dickinson)
- Solicit OSHA's involvement in the issues (Schreiber)
- Involve health agencies (ATSDR, CDC, etc.) in future discussions (Schreiber)
- Hold follow-up roundtable to build on key issues (Bourque)
- Advocate tax on perc or drycleaning services to pay for cleanup of contamination (Cohen)
- Develop inexpensive instrument to monitor indoor air emissions (Schreiber)
- Reduction of small-size exemption in EPA NESHAP (Bill Fisher)
- Amend EPA NESHAP to require dry-to-dry refrigerated "no-vent" (or equivalent) for new or reconstructed facilities
- Control/prohibition of new facilities in residential buildings
  - needs to be discussed
- Industry needs to be allowed to eliminate separator water discharges
  - general permit to allow evaporation should be sought
- Need multimedia/multiagency coordination on regulation
- Joint work between agencies and industry on methods of reducing/eliminating vapor transfer
- Develop financial mechanism for cleanup of contamination
- Develop joint industry/government position on carcinogenicity and toxicity

Follow-Up Activities

Finally, several participants, led by Ross Beard and Margaret Round, asked the EPA organizers to discuss their expectations for the roundtable and the type of follow-up to expect. Bob Lee of the Office of Pollution Prevention & Toxics (OPPT) explained that the roundtable is an example of some of the new non-regulatory activities that his office is working on to foster communication on pollution prevention issues. Libby Parker, also of OPPT, added that one of the main goals was to bring together a diverse group of experts that would ordinarily not get a chance to discuss ideas for pollution prevention related to drycleaning. This objective was applauded by the roundtable participants, who indicated that the roundtable format had fostered a unique and valuable exchange of views.

Libby Parker also discussed, to the extent possible at the time, the follow-up activities that EPA would be pursuing. The first of these, of course, is publication of the proceedings from the roundtable, complete with a summarized report on each discussion session.

Following the roundtable, EPA managers at the office director level and higher would be briefed on the two days of meetings, to see what types of follow-up they may wish to commit resources to. Bob Lee added that while little could be said immediately concerning potential follow-up to the roundtable, OPPT would make an effort to keep the participants informed about any activities pursued.

APPENDIX A

Attendees List

Attendees List

PANELISTS

Ken Adamson
Drycleaner-Launderers Institute of Ontario
P.O. Box 91128 - Effort Square
Hamilton, Ontario L8N4G3
CANADA
(415) 522-4651
(415) 529-5856 FAX

Yoshitado Aoyama
Japan Cleaning Machinery Association
Tokyo Sensun Kikai
Seisakusho Company, Ltd.
6-2, Ohashi 1-chome
Megro-ku, Tokyo 153
Japan
81-3-3780-8783
81-3-5489-7075 FAX

L. Ross Beard
R.R. Street & Company
625 Enterprise Drive
Oak Brook, IL 60521
(708) 571-4242
(708) 571-4248 FAX

Dr. Elizabeth Bourque
Massachusetts Department of Health
305 South Street
Jamaica Plain, MA 02130
(617) 522-3700

Scott Brumburgh
Roundtable Facilitator
2801 Spencer Road
Chevy Chase, MD 20815
(301) 589-4237

Barry Bunte
Executive Director
California Fabricare Association
10615 South De Anze Boulevard
Cupertino, CA 95014-4456
(408) 252-1746
(408) 242-5951 FAX

Jeff Cantin
Sr. Economist
Eastern Research Group, Inc.
110 Hartwell Avenue
Lexington, MA 02173-3198
(617) 674-7315
(617) 674-2851 FAX

Caron Chess
Environmental Communication Research Program
Rutgers University
122 Ryder Lane
New Brunswick, NJ 08903
(908) 932-8795
(908) 932-7815 FAX

Wendy L. Cohen
Senior Water Resource Control Engineer
California Regional Water Quality Control Board
3443 Routier Road - Suite A
Sacramento, CA 95827-3098
(916) 361-5676
(916) 361-5686 FAX

Tom Cortina
Halogenated Solvents Industry Association (HSIA)
1225 19th Street, NW - Suite 300
Washington, DC 20036
(202) 223-5890
(202) 223-5979 FAX

Walther den Otter
TNO Cleaning Techniques Research Institute
P.O. Box 70 (2600 AB)
Schoemakerstraat 97
Delft, the Netherlands
31-15-6977-74
31-15-5602-58 FAX

Dr. Gregory Diachenko (HFF-413)
U.S. Food and Drug Administration
200 C Street, SW
Washington, DC 20204
(202) 205-4319

Elden Dickinson
Michigan Department of Public Health
Occupational Health Division
3423 North Logan Street
P.O. Box 30195
Lansing, MI 48909
(517) 335-8250

Faye Dworkin
Econmic Analysis Branch
Consumer Product Safety Commission
5401 West Bard Avenue
Bethesda, MD 20816
(301) 504-0962
(301) 504-0124 FAX

William (Bill) Fisher
International Fabricare Institute (IFI)
12251 Tech Road
Silver Spring, MD 20904
(301) 622-1900
(301) 236-9320 FAX

Tom Gause
Business Development Division
Washington District Office
U.S. Small Business Administration
1111 18th Street, NW - 6th Floor
P.O. Box 19993
Washington, DC 20036-9993
(202) 634-1500 x280
(202) 634-1803 FAX

Ohad Jehassi (TS-779)
Economics, Exposure & Technology Division
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 260-6911
(202) 260-0981 FAX

Brenda L. Jellicorse
Economist
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709
(919) 541-6116
(919) 541-5945 FAX

Pauline Johnston (ANR-445W)
Indoor Air Division
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 233-9051
(202) 233-9555 FAX

Patrick Kennedy (TS-779)
Environmental Assessment Branch
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 260-3916

Rajib Khettry
Waste Management Branch
Ontario Ministry of the Environment
14th Floor
2 St. Clair Avenue West
Toronto, Ontario
M4V1L5 Canada
(415) 323-5226

Junji Kubota
All Japan Laundry & Drycleaning Association
5-4 Ginza 7-Chome
Chuo-ku, Tokyo 104
Japan
81-3-3571-2391
81-3-3574-0866 FAX

Jack Lauber
New York State Department
of Environmental Conservation
50 Wolf Road
Albany, NY 12233-3254
(518) 457-7688
(518) 457-0794 FAX

Dr. Josef Kurz
Director of Research
Forschungsinstitut Hohenstein
Schloss Hohenstein
D-7124 Boennigheim
Germany
49-7143271-0
49-7143271-51 FAX

Robert E. Lee (TS-779)
Economics, Exposure & Technology Division
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202)260-1670
(202) 260-0981 FAX

Jerry Levine
Associate Director
Neighborhood Cleaners Association
116 East 27th Street
New York, NY 10016-8998
(212) 684-0945
(212) 725-4714 FAX

Lynn Luderer (PM-233X)
Office of Policy, Planning & Evaluation
U.S. Environmental Protection Agency
401 M Street
Washington, DC 20460
(202) 260-6995

Scott Lutz
Bay Area Air Quality Management District
939 Ellis Street
San Francisco, CA 94109
(415) 749-4676
(415) 749-5030 FAX

Cynthia Marvin
California Air Resources Board
P.O. Box 2815 (SSD)
Sacramento, CA 95812
(916) 327-5981
(916) 327-5621 FAX

John Meijer
International Fabricare Institute (IFI)
12251 Tech Road
Silver Spring, MD 20904
(301) 622-1900
(301) 236-9320 FAX

Dr. A.A. Munshi
New York City Department of Health
346 Broadway - Room 707E
New York, NY 10013
(212) 566-3075
(212) 566-3331 FAX

Jean E. (Libby) Parker (TS-779)
Economics, Exposure & Technology Division
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 260-0686
(202) 260-0981 FAX

Josée Portugais
Environment Canada
Place Vincent Massey
Ottawa, Ontario K1A0H3
(819) 953-1136
(819) 953-5595 FAX

Scott Prothero (TS-779)
Economics, Exposure & Technology Division
Office of Pollution Prevention & Toxics
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460
(202) 260-1566

Stephen Risotto
Executive Director
Center for Emissions Control
1225 19th Street, NW - Suite 300
Washington, DC 20036
(202) 785-4374
(202) 223-5979 FAX

Dr. Thomas Robinson
Halogenated Solvents Industry Alliance
Suite 300
1225 19th Street NW
Washington, DC 20036
(202) 223-5890
(202) 223-5979 FAX

Margaret Round
Northeast States for Coordinated Air Use Management
129 Portland Street
Boston, MA 02114
(617) 367-8540
(617) 742-9162 FAX

Avima M. Ruder
National Institute for Occupational Safety and Health (NIOSH)
4676 Columbia Parkway (R16)
Cincinnati, OH 45226
(513) 841-4481
(513) 841-4540 FAX

Dr. Judith Schreiber
Bureau of Toxic Substance Assessment
New York State Department of Health
2 University Place - Room 200
Albany, NY 12203-3313
(518) 458-6405
(518) 458-6434 FAX

Bill Seitz
Executive Director
Neighborhood Cleaners Association
116 East 27th Street
New York, NY 10016-8998
(212) 684-0945
(212) 725-4714 FAX

George Smith (MD-13)
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711
(919) 541-1549
(919) 541-5661 FAX

Dr. Edward Stein (N3718)
Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Avenue, NW
Washington, DC 20210
(202) 523-7111
(202) 523-7125 FAX

Shozo Tamura
General Manager
Nippon Mining Company
Six East 43rd Street
New York, NY 10017
(212) 682-5060

Dr. Bruce Tichenor
Air & Energy Engineering Research Laboratory
Indoor Air Division
U.S. Environmental Protection Agency
Research Triangle Institute
Research Triangle Park, NC 27711
(919) 541-2991
(919) 541-2157 FAX

Dr. Mary Ellen Weber (TS-779)
Director, Economics, Exposure & Technology Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(202) 260-0667
(202) 260-0981 FAX

Dr. Hans-Dietrich Weigmann
Associate Director of Research
TRI/Princeton
601 Prospect Avenue
P.O. Box 625
Princeton, NJ 08542
(609) 924-3150
(609) 683-7836 FAX

Dr. Manfred Wentz
Vice Pres. Technology & Environmental Affairs
R.R. Street & Company
625 Enterprise Drive
Oak Brook, IL 60521
(708) 571-4242
(708) 571-4248 FAX

OBSERVERS

Robert Alfrey
Underwriters Laboratories
333 Pfingsten Road
Northbrook, Il 60062
(708) 272-8800 (x3135)
(708) 272-7030 FAX

Joyce Chandler (EN-341W)
Stationary Source Compliance Division
Office of Air and Radiation
U.S. Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(703) 308-8713
(703) 308-8738 FAX

Jesica Davis-O'Hay
National Clothes Line
717 East Chelten Avenue
Philadelphia, PA 19114
(215) 843-9795
(215) 843-8511 FAX

Umesh Dhalakia (2AWM-AC)
Air Programs Office
U.S. EPA Region 2
26 Federal Plaza
Room 100
New York, NY 10279
(212) 264-6676

Jane Engert (EN-341W)
Stationary Source Compliance Division
Office of Air and Radiation
U.S. Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(703) 308-8677
(703) 308-8738 FAX

Earl Fisher, Editor
American Drycleaner
Crane Enterprises
500 North Dearborn Street - Suite 1100
Chicago, IL 61610
(312) 337-7700

Elizabeth Leppin
International Fabricare Institute
12251 Tech Road
Silver Spring, MD 20904
(301) 622-1900
(301) 236-9320 FAX

Fred Metz
Economics, Exposure & Technology Division
Office of Pollution Prevention and Toxics
U.S. Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(202) 260-0684

Marian Mudar
New York Facilities Corporation
50 Wolf Road
Albany, NY 12205

Alan J. Philips
Air Quality Laboratories
928 Seventh Street - Unit 6
Santa Monica, CA 91403
(310) 395-3888
(310) 393-5606 FAX

Dan Restalli
Underwriters Laboratories
333 Pfingsten Road
Northbrook, Il 60062
(708) 272-8800
(708) 272-7030 FAX

Shari Zuskin
Office of Water
U.S. Environmental Protection Agency
401 M Street SW
Washington, DC 20460
(202) 260-7130

APPENDIX B

Supplemental Material

Submissions from Judy Schreiber New York State Department of Health

Investigation of Indoor Air Contamination in Residences Above Dry Cleaners

October 1991

New York State Department of Health
Bureau of Toxic Substance Assessment

2 University Place
Albany, New York 12203-3399

New York State Department of Environmental Conservation
Division of Air Resuorces

50 Wolf Road
Albany, New York 12233-7010

EXECUTIVE SUMMARY

In response to a complaint, in 1990, an investigation in Mahopac, New York found elevated air concentrations of tetrachloroethene in apartments above a first floor dry cleaning facility. The highest level measured exceeded the Occupational Safety and Health Administration (OSHA) workplace standard (25 ppm or 170,000 mcg/cu.m). The present study was carried out to ascertain whether similar situations might exist elsewhere in the State.

The objective of this investigation was to determine if tetrachloroethene levels in the indoor air of residences located in the same building as dry cleaning facilities were higher than levels in residences not near a dry cleaner. Data were also collected to evaluate what cleaning equipment or other factors might be contributing to air contamination in the dwellings.

Dry cleaning facilites in the Capital District were surveyed. Of 102 dry cleaners listed in the yellow pages of the telephone book, 67 cleaned or pressed on the premises. Dwelling units located in the same building as a dry cleaner were considered potential study homes. Twenty apartments located above 14 dry cleaning establishments that clean or press on premises were identified. Of the fourteen dry cleaning establishments, six were eliminated from consideration because the apartments were vacant or used for storage purposes only. Another dry cleaner was eliminated from the study because only pressing was conducted on the premises, and one dry cleaning establishment did not use tetrachloroethene. Thus, six of 102 surveyed dry cleaners (6%) had occupied apartments above facilities which clean on premises using tetrachloroethene.

These six apartments were evaluated. Six additional apartments that had similar building and neighborhood characteristics without a nearby source of tetrachloroethene were selected as controls. At each location, both indoors and outdoors, two consecutive twelve-hour air samples were collected: the first from 7 AM to 7 PM (AM sample) and the second from 7 PM to 7AM (PM sample). All samples for a study residence and its control were collected concurrently. Each dry cleaning operation was also inspected on the same day. The type of dry cleaning equipment, the volume of tetrachloroethene used, the presence or detection of odors, building characteristics and other features of the dry cleaning operation were noted.

A wide variety of conditions within the dry cleaning establishments were found. Three of the dry cleaners use machines which require the clothes to be transferred between the wash and dry cycles (transfer machines). Two of the dry cleaning establishments use machines that conduct both wash and dry cycles in one machine and do not require transfer of clothing between cycles (dry-to-dry machines). Lastly, one dry cleaner used a very old dry-to-dry machine in poor operating condition. This dry-to-dry was considered separately.

Significantly elevated levels of tetrachloroethene were found in the indoor air of the apartments located above each of the dry cleaners in the AM samples (range 300 to 55,000 mcg/cu.m) compared to the control residences (range < 6.7 to 103 mcg/cu.m). Similar results were found in the PM samples where concentrations of tetrachloroethene in the study residences (range 100 to 36,500 mcg/cu.m) also greatly exceeded the concentrations in the control residences (< 6.7 to 77 mcg/cu.m). Although air concentrations in the apartments were usually less at night than during the day, the study residences always had higher concentrations of tetrachloroethene than the control residences. The tetrachloroethene concentrations in outdoor air near the dry cleaners were also significantly elevated compared to control locations away from the dry cleaners, and these levels were less than the indoor levels.

The type of dry cleaning machine was significantly associated with the concentration of tetrachloroethene found in the apartment above, even though only six residences were evaluated. The tetrachloroethene levels in the apartments above dry cleaners using transfer machines are significantly elevated (AM range 1730 to 17,000 mcg/cu.m and PM range 1350 to 14,000 mcg/cu.m) compared to those using dry-to-dry machines (AM range 300 to 440 mcg/cu.m and PM range 100 to 160 mcg/cu.m). The apartments above the old dry-to-dry unit had the highest concentrations of all (AM 55,000 and PM 36,500 mcg/cu.m).

Among the dry cleaner characteristics noted or measured, the best predictor of the level of tetrachloroethene in the apartment was the tetrachloroethene level at the pressing station in the dry cleaning establishment. However, this correlation and the lack of other significant correlations may be spurious, the result of small numbers of samples. A strong correlation was also found between AM and PM tetrachloroethene levels in the apartments.

REPORT ON AN INVESTIGATION OF INDOOR AIR IN RESIDENCES ABOVE DRY CLEANERS

List of Tables, Appendices and Attachments

Abbreviations:

mcg/cu.m - micrograms per cubic meter
ppb - parts per billion
ppm - parts per million
VOC - volatile organic chemical

Appendices and additional copies of this report are available on request from the NYS Department of Health, 2 University Place, Albany, N.Y. 12203-3399.

#12050660

Indoor Air Contamination in Residences
above Dry Cleaners

Introduction

Two recent New York State Department of Health (NYSDOH) investigations of indoor air in residences near dry cleaners found tetrachloroethene levels above the levels typically found in indoor air. In one case, the level of tetrachloroethene in an apartment above a dry cleaner was higher than the standard for workplace air.

NYSDOH conducted the present investigation to determine if these situations are widespread. The objective of this study was to determine if tetrachloroethene levels in the indoor air of residences located in the same building as dry cleaning facilities were higher than levels in residences not near a dry cleaner. Data were also collected to evaluate what cleaning equipment and practices might be contributing to air contamination in the dwellings.

In 1990, an investigation in Mahopac, New York, found elevated levels of tetrachloroethene in second and third floor apartments located directly above a first floor dry cleaning facility. A laundromat with dry cleaning equipment was also located in an adjacent building. The highest tetrachloroethene level detected in one apartment was 197,000 micrograms of tetrachloroethene per cubic meter of air (mcg/cu.m) measured over a twelve hour period, which is above the Occupational Safety and Health Administration (OSHA) standard (8-hour time weighted average) for workplace exposure (170,000 mcg/cu.m). Elevated tetrachloroethene levels in the apartment above the cleaners were observed even when the dry cleaning machines were not being operated (Putnam Co. Health Dept., 1990).

In West Seneca, New York, a level of 85 mcg/cu.m was detected in a home next door to a dry cleaning facility. The outdoor level was 140 mcg/cu.m (NYS Department of Health, 1989). Although these levels are below levels measured in Mahopac, they are well above the mean values reported in national studies of tetrachloroethene levels (USEPA, 1987; Shah and Heyerdahl, 1988).

In Germany, a number of studies have also found elevated levels of tetrachloroethene in residences near dry cleaners. The International Fabricare Institute, an association of professional drycleaners and launderers, also reports concentrations of tetrachloroethene in buildings near dry cleaning establishments. The results of these studies are presented in the Discussion Section of this report.

Methodology

Site Selection

In the summer of 1990, Capital District dry cleaning facilities were surveyed (Appendix A). The Yellow Pages of the telephone book listed 102 dry cleaners. A telephone survey identified 67 facilities with cleaning or pressing on the premises. Fourteen of these facilities were in buildings that also contained dwelling units and 15 others were within 50 feet of buildings with dwelling units. Thus, forty-three percent (29 of 67) of Capital District dry cleaners surveyed who clean or press on the premises are proximate to dwelling units. Of all the 102 dry cleaners surveyed, twenty-eight percent (29 of 102) are proximate to dwelling units.

Dwelling units located in the same building as a dry cleaner were considered potential study homes. The dry cleaner survey identified 20 apartments located above the 14 dry cleaning establishments that clean or press on the premises. Since most apartments above the dry cleaning establishments are owned by the proprietor of the dry cleaners, cooperation for sampling was first secured from the owner of the dry cleaners and then from the apartment dwellers. Six dry cleaning establishments were eliminated from consideration in the study because the apartments located above them were either vacant or only used for storage purposes. Also eliminated from the study were one dry cleaner where only pressing was conducted on the premises and one dry cleaning establishment that did not use tetrachloroethene. Thus, six of 102 surveyed dry cleaners (6%) had occupied apartments above facilities which clean on premises. Samples were collected at these six units, where the owners and residents agreed to participate.

Prior to sample collection, the dwelling was surveyed and the resident interviewed to determine the best room for sampling. Based on possible conduits to the dry cleaners (stairways, pipe chases, etc.) and the location of odors that residents had noticed previously, the room most likely to have the highest tetrachloroethene levels was chosen for sampling.

A control home, located at least 100 meters away from each dry cleaner was sampled at the same time. The control home was similar to the study home in building type, age and neighborhood (where possible), and was not near any obvious source of tetrachloroethene. The sample in the control home was collected in the living room or dining room. Outdoor air samples were taken near the dry cleaner and near the control home concurrently with indoor samples.

Initial Survey and Contact With Residents

Residents of dwelling units above dry cleaners and potential control homes were contacted by NYSDOH personnel initially using a door-to-door survey. A fact sheet on the study and a letter of introduction were provided to the residents to explain the purpose of the investigation (Appendix B). If residents were willing to participate, a permission form and a preliminary questionnaire (Appendix B) were completed with basic information (name, address, telephone number, availability). If residents were not at home, the written materials were left at the home. Names of residents not at home were determined from mailboxes or neighbors and telephone numbers were obtained from the telephone book. A second attempt to contact residents not at home was made by telephone or door-to-door.

Investigation of Dry Cleaner Operation

Staff of the New York State Department of Environmental Conservation (NYSDEC) accompanied the NYSDOH sampling team and inspected the dry cleaning operation on the sampling day. NYSDEC personnel noted the type of dry cleaning equipment, the volume of tetrachloroethene used, the presence of odors or detection of tetrachloroethene with a PID (photoionization detector), the relative quality of housekeeping operations involving tetrachloroethene, the location of emission points from the dry cleaning process and activities in the cleaner at the time air samples were collected in the apartments. Also noted were types of ceilings, openings in ceilings, missing ceiling tiles, pipe chases and other potential conduits. Table 1 summarizes this information for the six facilities. The field data are detailed in Appendix C.

Air Sampling

When residents were contacted to schedule a sampling date, an explanation of the sampling procedure was provided. They were requested not to introduce any freshly dry-cleaned clothes or furnishings into the dwelling during the week before the sampling date. Information provided on the questionnaire completed by the resident confirmed that these instructions were followed in most cases. However, one study resident (No. 2) did not answer the question regarding the introduction of dry cleaned clothes to the dwelling, and one study resident (No. 5) brought dry cleaned clothes into his home daily. Among the control residents, one (No. C5) acknowledged bringing dry cleaned clothes into the dwelling several days prior to the sampling date and one (No. C3) did not answer the question regarding the introduction of dry cleaned clothes.

Although the sampling protocol specified that windows and doors should be closed for the 24-hour period prior to sampling, there were differences in ventilation at the study and control residences. Due to the hot weather, the residents were not asked to keep windows closed. Windows were open during sampling periods at study residences No. 4 and 5, closed at study residences No. 3 and 6, and not specified for study residences No. 1 and 2. Windows were open during sampling periods at control residences No. C1, C2 and C5; closed at control residences No. C4 and C6, and not specified for control residence No. C3.

All samples for a study residence and its control were collected concurrently by equipment installed by NYSDOH personnel and operated by electronic timers. At each location, both indoors and outdoors, two consecutive twelve-hour samples were collected: the first from 7 AM to 7 PM (referred to as AM samples) and the second from 7 PM to 7 AM (referred to as PM samples). Each sample was collected using a 6-liter evacuated stainless steel canister. The sampling location, sampling time, and a floor plan of the dwelling were recorded on the sampling form. Samples were collected according to procedures in the Staten Island/ New Jersey Indoor Air Study (NYS Dept of Health, 1990).

Sample Analysis and QA/QC

Samples were analyzed by gas chromatography/mass spectrometry according to procedures in the Staten Island/New Jersey Indoor Air Study (NYS Dept. of Health, 1990). Quality control and quality assurance procedures are detailed in the same reference. The detection limit for tetrachloroethene with this method is 1.5 mcg/cu.m. Samples were additionally analyzed for: chloromethane, methylene chloride, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, benzene, toluene, hexane, o-xylene, m,p-xylenes and ethylbenzene. In some cases, sample dilution was required to accurately quantify very high levels of tetrachloroethene. When this situation occurred, the other analytes were not analyzed (NA) because the detection limits were unacceptably high.

Statistical Methods

Comparison of data from the study and control residences in this study were evaluated by the Student's t-test and the Mann-Whitney non-parametric test. Calculation of mean concentrations used a value of one half the limit of detection for values reported as non-detected. Correlation coefficients and other statistics were generated using SPSS/PC+ software (Norusis, 1988).

The Student t-test is designed to test the significance of the difference between the means of two groups with normally-distributed data. The resulting p-value indicates the probability that the difference between two means could have occurred by chance. By convention, a p-value equal to or less than 0.05 indicates that the means are significantly different. The Student t-test can also be used to evaluate a measurement made at an individual study residence compared to the mean of the control residences. A p-value equal to or less than 0.05 indicates that the study home result is significantly different than the mean of the controls.

The Mann-Whitney non-parametric test can be used to compare two groups having a small number of samples. In this statistical test, all the tetrachloroethene results for a sampling period for study and control residences are combined into one group and ranked. If the study residences and control residences had similar tetrachloroethene levels, we would expect to find homes from each group located throughout this ranking. If there were a significant difference between the tetrachloroethene levels in the two types of residences, more residences in one group would be ranked higher than the other group. A p-value equal to or less than 0.05 indicates there is a significant difference between the two groups.

The strength of an association between continuous variables is assessed by the correlation coefficient R^2. The closer the R^2 is to 1.0, the more closely associated are the two variables. The strength of the association between a discrete variable and a continuous variable is assessed by the analysis of variance (ANOVA). A p-value of equal to or less than 0.05 indicates statistical significance for both correlation coefficients and ANOVA relationships.

Results

Facility Operating Characteristics

A wide variety of conditions were found within the dry cleaning establishments (See Table 1). Three of the dry cleaners (No. 2, 3 and 4) use machines which require the clothes to be transferred between the wash and dry cycles. These are referred to as transfer machines. Two of the dry cleaning establishments (No. 5 and 6) use machines that conduct both wash and dry cycles in one machine and do not require transfer of clothing between cycles. These are referred to as dry-to-dry machines. Lastly, one dry cleaner (No. 1) used a very old dry-to-dry machine in poor operating condition. Because the results of air sampling at the dry cleaning facility using this machine and the adjacent study residence were so different than their counterparts, this dry-to-dry machine is considered separately from the other dry-to-dry machines.

Tetrachloroethene Levels

Tetrachloroethene results for study homes, control homes and ambient air are summarized in Tables 2 and 3. The results indicate clearly elevated levels of tetrachloroethene in the indoor air of the apartments located above each of the dry cleaners (range from 300 to 55,000 mcg/cu.m) compared to the control residences (range from <6.7 to 103 mcg/cu.m) for AM 12-hour samples (Table 2). Similar results were found for the indoor air PM 12-hour samples where concentrations ranged from 100 to 36,500 mcg/cu.m in apartments above the dry cleaners while the control residences ranged from <6.7 to 77 mcg/cu.m. Outdoor air near the dry cleaners for the AM and PM samples were also elevated compared to controls (Table 2).

A comparison of PM and AM indoor air concentrations of tetrachloroethene in the study residences indicates that the PM air concentrations are almost always lower than the concentrations measured in the corresponding AM samples. It is notable that the levels of tetrachloroethene in the study residences do not decrease to control residence levels in the PM sampling period, but remain substantially elevated despite the discontinuation of the active use of the dry cleaning machines during the PM sampling period. Interestingly, at study residence No. 6, the levels of terachloroethene actually increased in the PM sampling period for both indoor and outdoor sample locations. According to the dry cleaner at this location, no dry cleaning was conducted there during the PM sampling period.

Table 3 summarizes tetrachloroethene levels in indoor and ambient samples grouped according to the type of dry cleaning unit in the dry cleaners below the study residences. The indoor air concentrations of tetrachloroethene of residences located above dry cleaners using transfer machines were much higher (1730 to 17,000 mcg/cu.m) than the concentrations found in residences located above dry cleaners using dry-to-dry machines (300 to 440 mcg/cu.m). The residence above dry cleaner No.1 with the old dry-to-dry unit, had the highest indoor air concentration of tetrachloroethene (55,000 mcg/cu.m) of all the residences studied. Among the control residents, one (No. C2) works in a chemical laboratory and one (No. C5) works at a dry cleaning facility. Both of these residences had higher concentrations of tetrachloroethene indoors than the other control residences.

Other Volatile Organic Chemicals (VOCs)

Tables 4 and 5 present the range and mean concentrations of all the volatile organic chemicals (VOCs) analyzed in the indoor AM and PM air samples, respectively. Tables 6 and 7 present the range and mean concentrations of all the VOCs analyzed in the ambient AM and PM air samples, respectively. One ambient sample at control residence No. 4 had elevated levels of benzene and toluene, possibly related to gasoline. With the exception of this ambient sample and the tetrachloroethene results at study residences, the VOCs tested in the study and control air samples were comparable to findings of the National VOC Database and the Total Exposure Assessment Methodology (TEAM) Studies. In the TEAM Study, the U.S. Environmental Protection Agency reported a mean tetrachloroethene level for indoor air of 10.7 mcg/cu.m and a mean outdoor level of 6.04 mcg/cu.m (EPA, 1987). The EPA National Ambient Volatile Organic Chemicals (VOCs) Database reports a mean tetrachloroethene level in indoor air of 20.7 mcg/cu.m (Shah and Heyerdahl, 1988).

Discussion

The statistical analysis of the data from this study is hindered by the small number of samples (6 study residences and 6 control residences) and by the lack of normally-distributed data in the study residences. The lack of normal distribution of results in the study residences violates the statistical assumptions underlying the use of the Student's t-test. The Mann-Whitney non-parametric test, however, avoids the problem of non-normal distribution by assigning ranks to the concentrations measured.

Statistically significant differences in mean tetrachloroethene concentrations between study and control residences, as evaluated by the Mann-Whitney test, were found for indoor air AM samples, indoor air PM samples, outdoor air AM samples and outdoor air PM samples.

The Student t-test can be used to evaluate a measurement made at an individual study residence compared to the mean of the control residences, because the control data are normally distributed. All comparisons of individual study residence tetrachloroethene concentrations (indoor and outdoor, AM and PM) to the mean of the control residences were statistically significant by the individual Student's t-test. (The Mann-Whitney test can not be used to evaluate individual test results).

This study evaluated characteristics of the dry cleaning facility which potentially impact the tetrachloroethene concentration in the indoor air of the apartment above the facility. Some of these characteristics may be expressed quantitatively, such as the number of machines in use and the concentration of tetrachloroethene at various locations in the facility. However, many characteristics are subjective and/or qualititive such as the presence and intensity of odors, the existence of conduits to the upstairs residence and the maintanance and upkeep of the facility. The small number of dry cleaning facilities and residences evaluated in this study limits the conclusions that can be extrapolated to the larger population of dry cleaning facilites and adjacent apartments.

Statistical comparisons were made to see if correlations exist between tetrachloroethene levels in the study residences and the type of dry cleaning equipment or operating characteristics of the dry cleaning facility. The variables used for these analyses are shown in Appendix D. This study included the measurement of continuous variables (such as the concentrations of tetrachlorethene and othe VOCs) and discrete variables (such as the type of dry cleaning equipment). Discrete variables are those that have an assigned arbitrary value to represent a category. The discrete variables evaluated in this study are dry cleaner type, ceiling type and vent locations.

The six dry cleaning facilities were categorized into three groups: those with transfer machines (3), those with dry-to-dry units (2) and one with a poor quality dry-to-dry unit. Despite the small number of facilities in each category, a statistically significant association was found between both the AM and PM indoor air concentrations of tetrachloroethene in the apartments above the dry cleaner and the type of dry cleaning machine used in the facility, as evaluated by ANOVA. The residences above dry cleaners using transfer machines had significantly higher tetrachloroethene concentrations in the AM and PM indoor air samples compared to those above dry cleaners using dry-to-dry machines. The residence above the old dry-to-dry unit had the highest tetrachloroethene level of any residence studied.

The location of the exhaust vents in a dry cleaning facility with respect to the tetrachloroethene levels in the study apartments was also assessed by ANOVA. The association was not significant. The type of ceiling in the dry cleaning establishment with respect to the tetrachloroethene levels in the study apartments was also not significant by ANOVA. The lack of significance for these variables (vent location and ceiling type) may be a function of the very small numbers available in each category. Of the three discrete variables studied, only dry cleaner machine type had a statistically significant association with the level of tetrachloroethene detected in the apartment above.

The continuous variables which were found to be highly correlated with AM indoor air tetrachloroethene concentrations at statistically significant levels ($p < 0.05$) were 1) indoor air PM tetrachloroethene concentrations ($R^2 = 0.98$), and 2) the maximum tetrachloroethene concentrations at the dry cleaner pressing station ($R^2 = 0.93$). Variables which were not correlated with indoor air tetrachloroethene concentrations included the tetrachloroethene concentrations measured at the front of the dry cleaning machine (washer or dryer) at the exhaust fan, and at the garment area. All of the associations as well as lack of associations should be considered tentative at best since the small numbers of samples and wide range of tetrachloroethene concentrations weaken the conclusions which can be drawn.

Other Studies

Several studies conducted in Germany have evaluated indoor air quality in residences near dry cleaners. Schaefer and Hohmann (1989) found a range of indoor air tetrachloroethene concentrations of 30 to 28,000 mcg/cu.m in apartments adjacent to dry cleaners. Fifty percent of the 38 apartments studied were found to contain tetrachloroethene concentrations greater than 1,000 mcg/cu.m based on a 7-day air sample. Buildings with concrete floors separating the dry cleaner from the apartments had lower concentrations in the apartment than buildings with wood beam floors. Of seventeen buildings with wood beam floors separating the dry cleaners from the apartments, seventy-six percent exceeded 1,000 mcg/cu.m tetrachloroethene in the indoor air of the apartment. Of twenty one buildings with concrete floors separating the dry cleaners from the apartments, twenty nine percent exceeded 1,000 mcg/cu.m tetrachloroethene in the indoor air of the apartment.

Six residences were monitored before and after cleanup measures were taken in the dry cleaner. Cleanup measures included installation of exhaust devices between floors, covering floors with aluminum foil, control of leaks and disposal of distillation residues. Tetrachloroethene levels in the indoor air of apartments decreased after cleanup: the mean tetrachloroethene level was 7,000 mcg/cu.m before cleanup and 2,500 mcg/cu.m after cleanup measures. However, fifty percent of the residences still exceeded 1,000 mcg/cu.m tetrachloroethene in the indoor air after cleanup measures.

Reinhard, Dulson and Exner (1989) collected 10-minute air samples every half hour from 8 AM to 7:30 PM in five apartments near dry cleaners and one control apartment. Mean concentrations of tetrachloroethene in indoor air of the study apartments ranged from 200 to 1,400 mcg/cu.m (5 of the 6 means were below 1,000 mcg/cu.m). The mean tetrachloroethene level in the control apartment was 2 mcg/cu.m. Concentrations within each apartment varied considerably at different times of the day.

The International Fabricare Institute (1990) recently studied the impact of tetrachloroethene from dry cleaners on adjacent locations. Passive monitoring badges were used to measure 8-hour time-weighted average (TWA) concentrations in locations adjacent to 21 dry cleaning plants. Fifteen of the plants used transfer equipment and six used dry-to-dry equipment. The mean TWA for tetrachloroethene for all 21 adjacent locations was 73,900 mcg/m^3. The International Fabricare Institute reported that the most common causes of tetrachloroethene levels in adjacent areas included problems with the ventilation system, accumulation of tetrachloroethene over suspended ceilings and locations of buildings in relation to wind currents (IFI, 1990).

Several studies (Schaefer and Hohman, 1989; Reinhard, Dulson and Exner, 1989; Vieths et al., 1987; Vieths et al., 1988) found that fat-containing foods (such as butter, cream, vegetable oil, margarine, sausage and cheese) can become contaminated with tetrachloroethene when stored in residences or food stores near dry cleaners. Tetrachloroethene levels in such foods increased with the amount of time that they were stored near a dry cleaner.

Tetrachloroethene has been found in butter and margarine samples obtained from retail stores located next to or near dry cleaners in the United States (Miller and Uhler, 1988; Entz and Diachenko, 1988). The samples were analyzed as part of a U.S. Food and Drug Administration monitoring program. The samples from stores with no dry cleaning establishments nearby generally contained less than 50 parts per billion (ppb) of tetrachloroethene. Samples from stores near dry cleaning establishments had tetrachloroethene concentrations ranging from 100 to more than 1,000 ppb. (Food was not analyzed as part of this NYSDOH study.)

Conclusions

Although based on a small number of samples, the following conclusions can be made:

1. The tetrachloroethene levels in air in the apartments above dry cleaners were significantly elevated (AM range 300 to 55,000 mcg/cu.m; PM range 100 to 36,500 mcg/cu.m) compared to local control apartments (AM range $<$6.7 to 103 mcg/cu.m; PM range $<$6.7 to 77 mcg/cu.m). Although air concentrations were usually less at night

than during the day, the study residences always had higher concentrations of tetrachloroethene than the control residences.

2. Tetrachloroethene concentrations in outdoor air near the dry cleaners were also significantly elevated (AM range 195 to 2600 mcg/cu.m; PM range 66 to 1400 mcg/cu.m) compared to control locations away from the dry cleaners (AM range <6.7 to 21 mcg/cu.m; PM range <6.7 to 6.9 mcg/cu.m).

3. The tetrachloroethene levels in the apartments above dry cleaners using transfer-type dry cleaning machines are significantly elevated (AM range 1730 to 17,000 mcg/cu.m; PM range 1350 to 14,000 mcg/cu.m) compared to those using dry-to-dry machines (AM range 300 to 440 mcg/cu.m; PM range 100 to 160 mcg/cu.m). One dry cleaner using an old dry-to-dry machine, however, had the highest levels of all (AM 55,000 mcg/cu.m; PM 36,500 mcg/cu.m).

4. Among all the dry cleaner characteristics noted or meaured, the best predictor of the level of tetrachloroethene in the apartment was the tetrachloroethene level at the pressing station in the dry cleaner establishment. Due to very small numbers of samples, few associations could be made between the conditions at the dry cleaner and the level of tetrachloroethene in the apartment air.

References:

Entz, R. and G. Diachenko. 1988. Residues of volatile halocarbons in margarines. Food Addit. Contam. 5: 267-276.

International Fabricare Institute (IFI), 1990. Monitoring Solvent Vapors in Dry Cleaning Plants. Focus on Dry Cleaning. 14: 6.

Miller, L. and A. Uhler. 1988. Volatile Halocarbons in butter: Elevated Tetrachloroethylene levels in samples obtained in close proximity to dry cleaning establishments. Bull. Environ. Contam. Toxicol. 41: 469-474.

New York State Department of Health, 1989. Interoffice Memorandum to Charles Hudson from Stanley House; October 12, 1989; Subject Air Sampling of Home in West Seneca, New York.

New York State Department of Health. 1990. Quality Assurance Project Plan: Staten Island/New Jersey Indoor Air Study.

Norusis, M. 1988. SPSS/PC+Studentware, SPSS Inc., Chicago Ill.

Putnam County Health Department, New York State Department of Environmental Conservation, New York State Department of Health, 1990. Investigation of tetrachloroethene in the Mahopac Business District.

Reinhard, K., W. Dulson and M. Exner. 1989. Concentrations of tetrachloroethylene in indoor air and food in apartments in the vicinity of dry cleaning shops. Zbl. Hyg. 189: 111-116. (In German)

Schaefer, J. and H. Hohmann. 1989. Tetrachloroethene pollution of residents adjacent to dry cleaners. Off. Gesundh.-Wes. 51: 291-295. (In German)

Shah, J.J. and E.K. Heyerdahl, 1988. National Ambient Volatile Organic Compounds (VOCs) Data Base Update. U.S. Environmental Protection Agency. Research Triangle Park, NC.

U.S. Environmental Protection Agency, 1987. The Total Exposure Assessment Methodology (TEAM) Study: Elizabeth and Bayonne, NJ, Devils Lake, ND and Greensboro, NC: Volume II. PB88-100078. Research Triangle Park, NC.

Vieths, S., W. Blaas, M. Fischer, C. Krause, I. Mehlitz and R. Weber. 1987. Contamination of foodstuffs by emission of tetrachloroethene from a dry-cleaning unit. Z. Lebensm. Unters. Forsch. 185: 267-270. (In German)

Vieths, S., W. Blaas, M. Fischer, C. Krause, R. Matissek, I. Mehlitz and R. Weber. 1988. Contamination of foodstuffs by emissions from dry cleaning units. Z. Lebensm. Unters. Forsch. 186: 393-397. (In German)

91263PRO0260

Table 1
Dry Cleaner Survey Operations Information

July, 1991

Dry Cleaner	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Machine Type	dry to dry (old)	transfer	transfer	transfer	dry to dry	dry to dry
No. Machines (cleaning)	2	1	1	1	1	1
Capacity (lbs/machine)	10	35-40	20	20	35	50
Total solvent used (gal/month)	NR[1]	50	12	25	17	NR[2]
Local exhaust (from machine) to outdoors	vent in first floor wall (both machines)	vent in first floor wall	vent in first floor wall	dryer-vent in first floor wall washer-vent to roof	carbon adsorber on vent which exhausts to room	no vents (recir-culated to machine)
General exhaust (room exhaust)	2 window fans (12")	2 fans in walls (24") 1 fan in ceiling (18")	2 window fans	5 fans in windows and walls (12" and 18")	7 wall fans (22" and 10")	2 fans in wall (24" and 48")
<u>Maintenance</u>						
Equipment leaks	yes	yes	yes	no	yes	no
Perc/water separator fugitive emissions	yes	no	yes	yes	yes	no
Open containers	no	no	no	no	no	no
<u>Building characteristics</u>						
Ceiling type	suspended	metal (tiles missing)	suspended	plaster	plaster	tin
Pipe chases in ceiling	yes	yes	yes	yes	no	no
Odor intensity	low (machines not operating)	medium	medium	medium	low	low

[1] NR = not reported by owner

[2] NR = not reported by field staff

#12040124

Table 1 (continued)
Dry Cleaner Survey Operations Information
Real-time Tetrachloroethene Air Measurements (ppm)[c]

July, 1991

Dry Cleaner	No. 1[d]	No. 2	No. 3	No. 4	No. 5	No. 6
Instrument	Photovac	HNU	HNU	HNU	HNU	HNU
Front of machine(s)[a]	150	12	100	50	10	3
Behind machines(s)[a]	> 200[b]	200	100	350	150	3
Front mach(s)/door open[a]	100	300	320	400	3	300
Carbon adsorber	NA	NA	NA	NA	2-3 (at vent)	6 (on machine)
Outside @ exhaust fan						
Washer	60 (fan off)	-	8-15	-	-	-
Dryer	-	190	320-400	250	-	-
Room	-	-	-	-	2-10	1-2
Pressing station	30-80	9-10	2-3	10-13	1-2	2-3
Garments	NR	7-15	5-12	7-10	< 1-25	70

PPM = parts per million

NR = not reported

NA = not applicable

a = highest level recorded at washer or dryer

b = maximum reading for the Photovac detector is 200 ppm.

c = instruments calibrated to benzene

d = measurement made at Dry Cleaner on different day than residential air sampling due to air sampler malfunction

#12040124

Table 2

Tetrachloroethene Concentrations for Study and Control Residences (mcg/cu.m)

Residence	Tetrachloroethene Indoor		Tetrachloroethene Outdoor	
	AM	PM	AM	PM
<u>Study Homes</u>				
Residence 1 (O)	55,000	36,500	2,600	360
Residence 2 (T)	17,000	14,000	1,400	1,400
Residence 3 (T)	3,850	8,380	530	812
Residence 4 (T)	1,730	1,350	1,110	441
Residence 5 (D)	440	160	195	66
Residence 6 (D)	300	100	300	400
<u>Control homes</u>				
Residence C1	< 6.7	< 6.7	< 6.7	< 6.7
Residence C2	103	77	21	< 6.7
Residence C3	< 6.7	< 6.7	< 6.7	< 6.7
Residence C4	< 6.7	< 6.7	< 6.7	< 6.7
Residence C5	44	56	< 6.7	< 6.7
Residence C6	9.7	22	16	6.9

Study residence above dry cleaner using:
O = old dry-to-dry unit
D = dry-to-dry unit
T = transfer unit

cvm/91205PRO0286

Table 3
Summary of Tetrachloroethene concentrations for Study and Control Residences (mcg/cu.m)

Sample Type/Residence Type (number)	Tetrachloroethene	
	Range	Mean
Indoor Air, AM		
Study homes (6)	300-55,000	13,000
above 'transfer' cleaners (3)	1,730-17,000	7,500
above 'dry-to-dry' cleaners (2)	300-440	370
above old dry-to-dry unit (1)	55,000	55,000
Control homes (6)	< 6.7-103	28
Indoor Air, PM		
Study homes (6)	100-36,500	10,000
above 'transfer' cleaners (3)	1,350-14,000	7,900
above 'dry-to-dry' cleaners (2)	100-160	130
above old dry-to-dry unit (1)	36,500	36,500
Control homes (6)	< 6.7-77.0	28
Outdoor Air, AM		
Study homes (6)	195-2,600	1,000
outside 'transfer' cleaners (3)	530-1,400	1,000
outside 'dry to dry' cleaners (2)	195-300	250
outside old dry-to-dry unit (1)	2,600	2,600
Control homes (6)	< 6.7-21	8.4
Outdoor Air, PM		
Study homes (6)	66-1,400	580
outside 'transfer' cleaners (3)	441-1400	880
outside 'dry-to-dry' cleaners (2)	66-400	230
outside old dry to dry unit (1)	360	360
Control homes (6)	< 6.7-6.9	3.9

cvm/91205PRO0286

Table 4
Range and Mean Volatile Organic Chemical Concentrations in Indoor Air (AM) Compared to Other Studies (mcg/cu. m)

VOC	This Study				Other Studies		
	Study Homes (6)		Control Homes (6)		Team Study Range[a]	Team Mean[a]	Mean VOC[b]
	Range	Mean[d](n)	Range	Mean[d](n)			
Chloromethane	NA - 2.3	c	2.4 - 4.5	3.2(6)	-	-	-
Methylene Chloride	NA - <3.4	c	<3.4 - 15	6.5(6)	-	-	-
Hexane	NA - <3.5	c	<3.4 - 4.0	2.4(6)	-	-	2.0
Chloroform	NA - <4.8	c	<4.8	2.4(6)	0.05 - 215.0	6.7	4.1
1,1,1-Trichloroethane	NA - <5.4	c	7.4 - 180	45(6)	0.08 - 8300	80.0	267.0
Carbon tetrachloride	NA - <6.2	c	<6.2	3.1(6)	0.11 - 1100.	10.1	2.5
Benzene	NA - 7.5	c	<3.2 - 7.6	3.6(6)	0.02 - 510	28.4	16.5
Trichloroethene	NA - <5.3	c	<5.3	2.7(6)	0.07 - 350	6.0	7.2
Toluene	NA - 100	52(3)	5.7 - 31	19(6)	-	-	31.7[e]
Tetrachloroethene	300 - 55,000	13,000(6)	<6.7 - 103	28(6)	0.07 - 250	10.7	20.7
Ethylbenzene	NA - 13	c	<4.3 - 4.7	2.6(6)	0.02 - 380	10.6	12.5
m,p-Xylene	NA - 46	c	<4.3 - 16	9.5(6)	0.02 - 3100	40.0	37.6
o-Xylene	NA - 22	c	<4.3 - 7.8	5.2(6)	0.02 - 750	12.5	12.3

NA = Not analyzed

a = Data from Total Exposure Assessment Methodology (TEAM) study, indoor overnight air samples (US EPA, 1987)

b = Data from EPA Volatile Organic Compounds Database, indoor air (Shah and Heyerdahl, 1988)

c = Mean not calculated. (Only one sample was analyzed for this chemical.)

d = For non-detectable results, a value of one half the detection limit is used to calculate the mean

e = Median

cvm/12050006

Table 5
Range and Mean Volatile Organic Chemical Concentrations in Indoor Air (PM) Compared to Other Studies (mcg/cu.m)

VOC	This Study				Other Studies		
	Study Homes (6)		Control Homes (6)		Team Study Range[a]	Team Mean[a]	Mean VOC[b]
	Range	Mean[d](n)	Range	Mean[d](n)			
Chloromethane	NA - 2.3	c	<2.0 - 3.9	2.4(6)	-	-	-
Methylene Chloride	NA - 4.7	c	<3.4 - 16	8.2(6)	-	-	-
Hexane	NA - <3.5	c	<3.5 - 4.2	2.9(6)	-	-	2.0
Chloroform	NA - <4.8	c	<4.8	2.4(6)	0.05 - 215.0	6.7	4.1
1,1,1-trichloroethane	NA - 75	39(2)	6.9 - 197	55(6)	0.08 - 8300	80.0	267.0
Carbon tetrachloride	NA - <6.2	c	<6.2	3.1(6)	0.11 - 1100.	10.1	2.5
Benzene	NA - 4.2	c	<3.2 - 9.9	3.5(6)	0.02 - 510	28.4	16.5
Trichloroethene	NA - <5.3	c	<5.3	2.7(6)	0.07 - 350	6.0	7.2
Toluene	NA - 85	48(3)	7.4 - 29	20(6)	-	-	31.7[e]
Tetrachloroethene	100 - 36,500	10,000(6)	<6.7 - 77.0	28(6)	0.07 - 250	10.7	20.7
Ethylbenzene	NA - 12.4	c	<4.3 - 5.9	3.3(6)	0.02 - 380	10.6	12.5
m,p-xylene	NA - 39	c	5.6 - 17	10(6)	0.02 - 3100	40.0	37.6
o-xylene	NA - 20	c	<4.3 - 8.6	5.0(6)	0.02 - 750	12.5	12.3

NA = Not analyzed

a = Data from Total Exposure Assessment Methodology (TEAM) study, indoor overnight air samples (US EPA, 1987)

b = Data from EPA Volatile Organic Chemical Database, indoor air (Shah and Heyerdahl, 1988)

c = Mean not calculated (only one sample was analyzed for this chemcial)

d = For non-detectable results, a value of one half the detection limit is used to calculate the mean

e = Median

cvm/12050006

Table 6
Range and Mean Volatile Organic Chemical Concentrations in Outdoor Air (AM) Compared to Other Studies (mcg/cu. m)

VOC	This Study				Other Studies		
	Study Homes (6)		Control Homes (6)		Team Study Range[a]	Team Mean[a]	Mean VOC[b]
	Range	Mean[c](n)	Range	Mean[c](n)			
Chloromethane	NA - 2.9	2.3(5)	2.0 - 3.1	2.5(6)	-	-	1.5
Methylene Chloride	NA - 3.9	2.5(5)	<3.4 - 17	5.3(6)	-	-	5.6
Hexane	NA - 4.2	2.2(5)	<3.5 - 3.7	2.1(6)	-	-	13
Chloroform	NA - <4.8	2.4(5)	<4.8	2.4(6)	0.04 - 230	5.3	3.1
1,1,1-Trichloroethane	NA - 9.8	4.1(5)	<5.4 - 27	8.6(6)	0.05 - 470	8.5	5.0
Carbon tetrachloride	NA - <6.2	3.1(5)	<6.2	3.1(6)	0.04 - 14	1.1	1.0
Benzene	NA - 30	12(5)	<3.2 - 7.6	3.4(6)	0.04 - 91	9.1	9.0
Trichloroethene	NA - <5.3	2.7(5)	<5.3	2.7(6)	0.06 - 106	4.0	2.7
Toluene	NA - 31	17(5)	7.1 - 67	20(6)	-	-	32
Tetrachloroethene	300 - 2,600	1,000(6)	<6.7 - 21	8.4(6)	0.04 - 95	6.0	5.8
Ethylbenzene	NA - 7.6	3.8(5)	<4.3 - 6.5	3.2(6)	0.02 - 39	3.7	20
m,p-Xylene	NA - 26	12(5)	<4.3 - 19	8.8(6)	0.02 - 70	11	46
o-Xylene	NA - 12	6.4(5)	<3.1 - 10	4.7(6)	0.02 - 31	3.8	33

NA = Not analyzed

a = Data from Total Exposure Assessment Methodology (TEAM) study, outdoor air samples (US EPA, 1987)

b = Data from EPA Volatile Organic Compounds Database, outdoor air (Shah and Heyerdahl, 1988)

c = For non-detectable results, a value of one half the detection limit is used to calculate the mean

cvm/#12120469

Table 7
Range and Mean Volatile Organic Chemical Concentrations in Outdoor Air (PM) Compared to Other Studies (mcg/cu. m)

VOC	This Study				Other Studies		
	Study Homes (6)		Control Homes (6)		Team Study Range[a]	Team Mean[a]	Mean VOC[b]
	Range	Mean[c] (n)	Range	Mean[c] (n)			
Chloromethane	NA - 6.5	3.1(5)	< 2.0 - 6.5	2.5(6)	-	-	1.5
Methylene Chloride	NA - < 3.4	1.7(5)	< 3.4 - 22	7.5(6)	-	-	5.6
Hexane	NA - 6.1	3.6(5)	< 3.5 - 9.2	3.3(6)	-	-	13
Chloroform	NA - < 4.8	2.4(5)	< 4.8	2.4(6)	0.04 - 230	5.3	3.1
1,1,1-Trichloroethane	NA - 8.0	4.4(5)	< 5.4 - 6.7	4.0(6)	0.05 - 470	8.5	5.0
Carbon tetrachloride	NA - < 6.2	3.1(5)	< 6.2	3.1(6)	0.04 - 14	1.1	1.0
Benzene	NA - 11	7.1(5)	< 3.2 - 242	50(6)	0.04 - 91	9.1	9.0
Trichloroethene	NA - < 5.3	2.7(5)	< 5.3	2.7(6)	0.06 - 106	4.0	2.7
Toluene	NA - 30	17(5)	< 3.8 - 93	31(6)	-	-	32
Tetrachloroethene	66 - 1,400	580(6)	< 6.7 - 6.9	3.9(6)	0.04 - 95	6.0	5.8
Ethylbenzene	NA - 6.7	4.0(5)	< 4.3 - 4.5	2.5(6)	0.02 - 39	3.7	20
m,p-Xylene	NA - 24	14(5)	< 4.3 - 18	8.8(6)	0.02 - 70	11	46
o-Xylene	NA - 11	6.6(5)	< 4.3 - 8.5	4.4(6)	0.02 - 31	3.8	33

NA = Not analyzed

a = Data from Total Exposure Assessment Methodology (TEAM) study, outdoor air samples (US EPA, 1987)

b = Data from EPA Volatile Organic Compounds Database, outdoor air (Shah and Heyerdahl, 1988)

c = For non-detectable results, a value of one half the detection limit is used to calculate the mean

cvm/#12120469

STATE OF NEW YORK
DEPARTMENT OF HEALTH

Center for Environmental Health 2 University Place Albany, New York 12203-3399

Lorna McBarnette
Executive Deputy Commissioner

OFFICE OF PUBLIC HEALTH
Linda A. Randolph, M.D., M.P.H.
Director
Sue Kelly
Executive Deputy Director
William N. Stasiuk, P.E., Ph.D.
Center Director

August 2, 1991

William Grattan, M.D.
Commissioner
Albany County Health Department
South Ferry & Green Streets
Albany, New York 12201

Dear Dr. Grattan:

This letter summarizes the toxicologic and epidemiologic data for tetrachloroethene that we discussed previously. The target organs for toxic effects following exposure to tetrachloroethene are the central nervous system, liver and kidneys.

In evaluating the health risks from tetrachloroethene exposure, we've followed the procedures outlined by the National Academy of Sciences (NAS, 1977, 1987) and federal agencies such as the U.S. Food and Drug Administration, the U.S. Environmental Protection Agency, and the Agency for Toxic Substances and Disease Registry (Dourson and Stara, 1983; US EPA 1988, 1989). We've identified either no-observed-effect levels or lowest-observed-effect levels for target organs in humans and animals. When developing exposure guidelines for long-term exposure of the general population from human data, uncertainty factors are used because effect or no-effect levels can be based on studies using healthy adults (frequently only men), short exposure times, small sample sizes and limited information on exposure levels. These same limitations may exist when using animal data, but additional uncertainty is introduced when extrapolating results from animals to humans. Uncertainty factors that are usually applied include a factor of ten for a short-term study, ten for using a lowest-observed-effect level rather than a no-observed-effect level and ten in going from a limited study in adults to the general population. Consideration may also be made for the quality and quantity of the available data.

Information on central nervous system effects comes from human controlled-chamber exposures and from epidemiological studies. The controlled studies used healthy adults and short exposure times. The epidemiological studies involved longer exposure times, but the exposure levels are less certain than for the controlled studies.

In controlled exposure studies, Stewart et al. (1970) and Hake and Stewart (1977) reported central nervous system effects when adult males and females were exposed to 100 ppm (690 milligrams per cubic meter--mg/m^3) for 7 or 7.5 hours per day for five days. Effects were not detected in adults exposed to 20 ppm (140 mg/m^3) for 7.5 hours per day for 5 days.

Workers exposed to tetrachloroethene have also been evaluated for possible central nervous system effects. A study by Lauwerys et al. (1983) did not detect adverse effects on the central nervous system of Belgian workers at dry cleaning shops who were exposed to a time weighted average (TWA) tetrachloroethene level of 21 ppm (145 mg/m³). Seeber (1989) summarized a series of studies which evaluated such endpoints as perceptual speed, digit reproduction and sensorimotor and coordination functions in German dry cleaning workers. The performance of both the high-exposed (reported TWA 360 mg/m³) and low-exposed (reported TWA 83 mg/m³) groups differed significantly from the control group for some tests; however, the two exposed groups did not differ from each other.

A guideline for central nervous system effects for the general population can be derived from the no-observed-effect level in controlled chamber experiments or from the worker studies. The no-observed-effect level for central nervous system effects in the controlled chamber studies is 20 ppm (140 mg/m³). Because this study was on healthy adults and of limited duration, an uncertainty factor of 100 is applied after averaging the concentration over 24 hours. This suggests a guideline of 0.4 mg/m³. The lowest effect level in the worker studies was 83 mg/m³. Because effects were observed and the study was on healthy adults, an uncertainty factor of 100 is needed after averaging the concentration over 24 hours. This suggests a guideline of 0.25 mg/m³.

The liver is also a target organ for tetrachloroethene, particularly in mice. Case reports of liver effects have also been reported in humans who were exposed to high concentrations, sometimes under severe circumstances. The lowest-observed-effect level for mice is 60 mg/m³, when continuously exposed for 30 days (Kjellstrand et al., 1984). Liver weights were significantly elevated. Using an inhaled dose to extrapolate the results from mice to humans and applying a thousand-fold uncertainty factor would suggest a guideline of about 0.25 mg/m³ for liver effects.

The kidney is also a target organ in rats. Effects were seen in rats exposed to 200 ppm (1,400 mg/m³) for 6 hours per day, 5 days per week for 2 years (NTP, 1986). These effects included nucleus enlargement and tubular cell hyperplasia. Using an inhaled dose to extrapolate from rats to humans and applying a thousand-fold uncertainty factor would suggest a guideline of about 0.5 mg/m³ for kidney effects.

Exposure to tetrachloroethene caused liver tumors in mice and mononuclear cell leukemias and kidney tumors in rats. The exact mechanisms by which these tumors were induced are not known. Because of the uncertainty, a conservative estimate of the tetrachloroethene air concentration corresponding to the upper bound on risk and associated with a one in one million excess lifetime human oncogenic risk is 0.05 micrograms per cubic meter (mcg/m³). This estimate is based on the assumptions that the delivered dose of the active carcinogenic agent is linearly proportional to inhaled dose of tetrachloroethene across all doses and that surface area is the appropriate parameter for dose extrapolation. Confidence in this estimate is limited by the data which indicate that linearity across all doses does not hold for the potential oncogenic agents (tetrachloroethene or its metabolites) and by the degree to which the results of empirical observations on the toxic effects of anti-neoplastic drugs (the source of the surface area rule) are applicable to chemicals which are metabolized differently.

Correlations between the metabolic and carcinogenic data can be used to support the hypothesis that the metabolic products of the mixed function oxidase pathway for tetrachloroethene are responsible for its carcinogenicity in mice. If the available data are used with physiologically-based pharmacokinetic modeling, an estimate of the air level corresponding to the upper bound on risk and associated with a one in one million excess lifetime human carcinogenic risk is 0.5 mcg/m^3 (if humans and mice are assumed to be equally sensitive to the same delivered dose). Confidence in this estimate is limited by the validity of the initial assumptions and the accuracy of the model in compensating for non-linearity when extrapolating from high to low doses and in compensating for differences in the capacity of mice and humans to metabolize tetrachloroethene by the mixed function oxidase pathway.

Correlations using urinary excretion data for tetrachloroethene metabolites can also be used to estimate an excess human cancer risk from the mouse liver tumor data. Using this method (US EPA, 1990), the tetrachloroethene air concentration corresponding to an upper bound on risk and associated with a one in one million excess lifetime human cancer risk is 2 mcg/m^3.

The NYS Department of Health recommends, based on an evaluation of the non-carcinogenic effects of tetrachloroethene, that the average ambient air level in a residential community not exceed 250 mcg/m^3 for adults, considering continuous lifetime exposure. If a child's inhalation rate and body weight are used, the guideline becomes 100 mcg/m^3. Furthermore, we recommend that the uncertainty factor not be reduced by more than an order of magnitude when considering the need to take immediate action. We also recommend that exposure to tetrachloroethene be minimized to the extent practical; e.g. regardless of the levels, solvent containers should not be left opened. The potential carcinogenic risks of tetrachloroethene will be considered further as regulations are developed for the dry cleaning industry.

Enclosed with this letter are the results for the other apartments in Albany County that were evaluated in the dry cleaner study and the draft report for the study. The results for both of these apartments exceed the criterion that we recommend for undertaking immediate action to reduce tetrachloroethene levels. We would appreciate any comments on the draft report by Friday August 9, 1991.

Please let us know when you are able to provide study participants with results for their homes. We will provide extra copies of the report when it is finalized for you to send to the study participants.

Sincerely,

Nancy Kim

Nancy Kim, Ph.D.
Director
Division of Environmental Health
Assessment

12030153

REFERENCES

Dourson, M.L. and Stara, J.F. 1983. Regulatory History and Experimental Support of Uncertainty (Safety Factors). Regulatory Toxicol. Pharmacol., 3: 224-238.

Hake, C.L. and Stewart, R.D. 1977. Human Exposure to Tetrachloroethylene: Inhalation and Skin Contact. Environmental Health Perspectives, 21: 231-238.

Kjellstrand, P., Holmquist, B., Kanje, M., Alm, P., Romare, S., Jonsson, I., Mansson, L., and Bjerkemo, M. 1984. Perchloroethylene: Effects on Body and Organ Weights and Plasma Butyrylcholinesterase Activity in Mice. Acta Pharmacol. Toxicol., 54: 414-424.

Lauwerys, R., Herbrand, J., Buchet, J.P., Bernard, A., and Gaussin, J. 1983. Health Surveillance of Workers Exposed to Tetrachloroethylene in Dry-cleaning Shops. Int. Arch. Occup. Environ. Health, 52: 69-77.

National Academy of Sciences. 1977. Drinking Water and Health, Volume 1. National Academy of Sciences, Washington, D.C.

National Academy of Sciences. 1987. Drinking Water and Health, Volume 7, National Academy of Sciences, Washington, D.C.

National Toxicology Program. 1986. Toxicology and Carcinogenesis Studies of Tetrachloroethylene (Perchloroethylene) (CAS no. 127-18-4) in F344/N Rats and $B6C3F_1$ Mice (Inhalation Studies). NTP Technical Report Series No. 311. NTP, Research Triangle Park, NC. NIH Publication No. 86-2567.

Seeber, A. 1989. Neurobehavioral Toxicity of Long-Term Exposure to Tetrachloroethylene. Neurotoxicology and Teratology, 11: 579-583.

Stewart, R.D., Baretta, E.D., Dodd, H.C., Torkelson, T.R. 1970. Experimental Human Exposure to Tetrachloroethylene. Arch. Environ. Health, 20: 224-229.

U.S. Environmental Protection Agency. 1990. Health Effects Assessment Summary Tables, Fourth Quarter, FY - 1990. Environmental Criteria and Assessment Office, Cincinnati, OH. NTIS No. PB90-921104.

U.S. Environmental Protection Agency. 1989. Interim Methods for Development of Inhalation Reference Doses. EPA/600/8-88/066F. Office of Health and Environmental Assessment, Washington, D.C.

U.S. Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, D.C.

12130371

Fact Sheet

AIR CONTAMINATION ABOVE DRY CLEANERS

February 1992

Prepared by

New York State
Department of Health

SUMMARY:

The New York State Department of Health (NYSDOH) and the New York State Department of Environmental Conservation (NYSDEC) conducted air sampling in 18 residences located above dry cleaning establishments in 1991. Elevated levels of tetrachloroethene, a dry cleaning solvent also known as "perc", were measured in the indoor air of these residences. NYSDOH and NYSDEC are taking actions to reduce residents' exposure to tetrachloroethene in residences located above dry cleaners.

ABBREVIATIONS:

mcg/cu.m	=	micrograms of tetrachloroethene per cubic meter of air
ppm	=	parts per million
1 ppm	=	6800 mcg/cu.m
NYSDOH	=	New York State Department of Health
NYSDEC	=	New York State Department of Environmental Conservation

INTRODUCTION

In response to an odor complaint, an investigation conducted in 1989 and 1990 in Mahopac, New York, found elevated air concentrations of tetrachloroethene in three of four apartments located in the same building as a dry cleaning facility. As a result of this finding, a study was conducted to determine if this situation is widespread. The objective of the study was to determine if tetrachloroethene levels in residences located in the same building as a dry cleaner were higher than levels in residences not near a dry cleaner. In 1991, the indoor air of six apartments located above six dry cleaners in the Albany, New York, area were evaluated. Later in 1991, three apartments above a dry cleaner in Westchester County and five apartments above a dry cleaner in New York City were tested. Control apartments, located in similar neighborhoods but not near a dry cleaner, were tested at the same time. Data were also collected to evaluate what cleaning equipment or other factors might be contributing to air contamination in the apartments.

QUESTIONS AND ANSWERS

What is tetrachloroethene?

Tetrachloroethene (also called perc or perchloroethylene) is a colorless liquid at room temperature. Tetrachloroethene is commonly used for dry cleaning fabrics. "Dry" cleaning machines use the liquid to wash clothes. Some of the liquid can evaporate into the air, producing an ether-like odor. It is also used in degreasing metals and is found in some consumer products such as paint removers, water repellants, spot removers, auto brake cleaners, adhesives and suede protectors. Because tetrachloroethene is so widely used, it is commonly found in outdoor and indoor air. Measurements have been made in air quality studies across the United States. The average outdoor air levels in these studies ranged from 1.9 to 4.0 micrograms of tetrachloroethene per cubic meter of air (mcg/cu.m). The average indoor tetrachloroethene levels ranged from 6.2 to 13 mcg/cu.m.

What were the results of the sampling?

The test results show that tetrachloroethene was found in the indoor air of apartments above dry cleaners at levels considerably higher than the levels found in control apartments not near dry cleaners. The concentration in apartments above dry cleaners ranged from 100 to 62,000 mcg/cu.m and in apartments away from dry cleaners ranged from less than 6.7 to 103 mcg/cu.m.

How am I exposed to tetrachloroethene and can it affect my health?

Tetrachloroethene can enter the body in food we eat, in water we drink and in the air we breath. With exposures from dry cleaners, the greatest amount is from breathing air containing tetrachloroethene. Health effects that may result from breathing air containing tetrachloroethene are shown in the attached diagram. Exposure to high levels of tetrachloroethene (680,000 mcg/cu.m and greater) can cause immediate health effects such as dizziness, headaches and sleepiness. Health effects from exposure to low levels of tetrachloroethene are less well known. Animal studies suggest that exposure for months or years to elevated levels of tetrachloroethene may cause liver and kidney damage, effects on the unborn, liver cancer and leukemia. There is not enough information to show if tetrachloroethene exposure can increase the risk of cancer in humans.

Based on an evaluation of the information from humans and laboratory animals, the NYSDOH has recommended that average levels of tetrachloroethene in indoor air not exceed 100 mcg/cu.m.

What action is being taken?

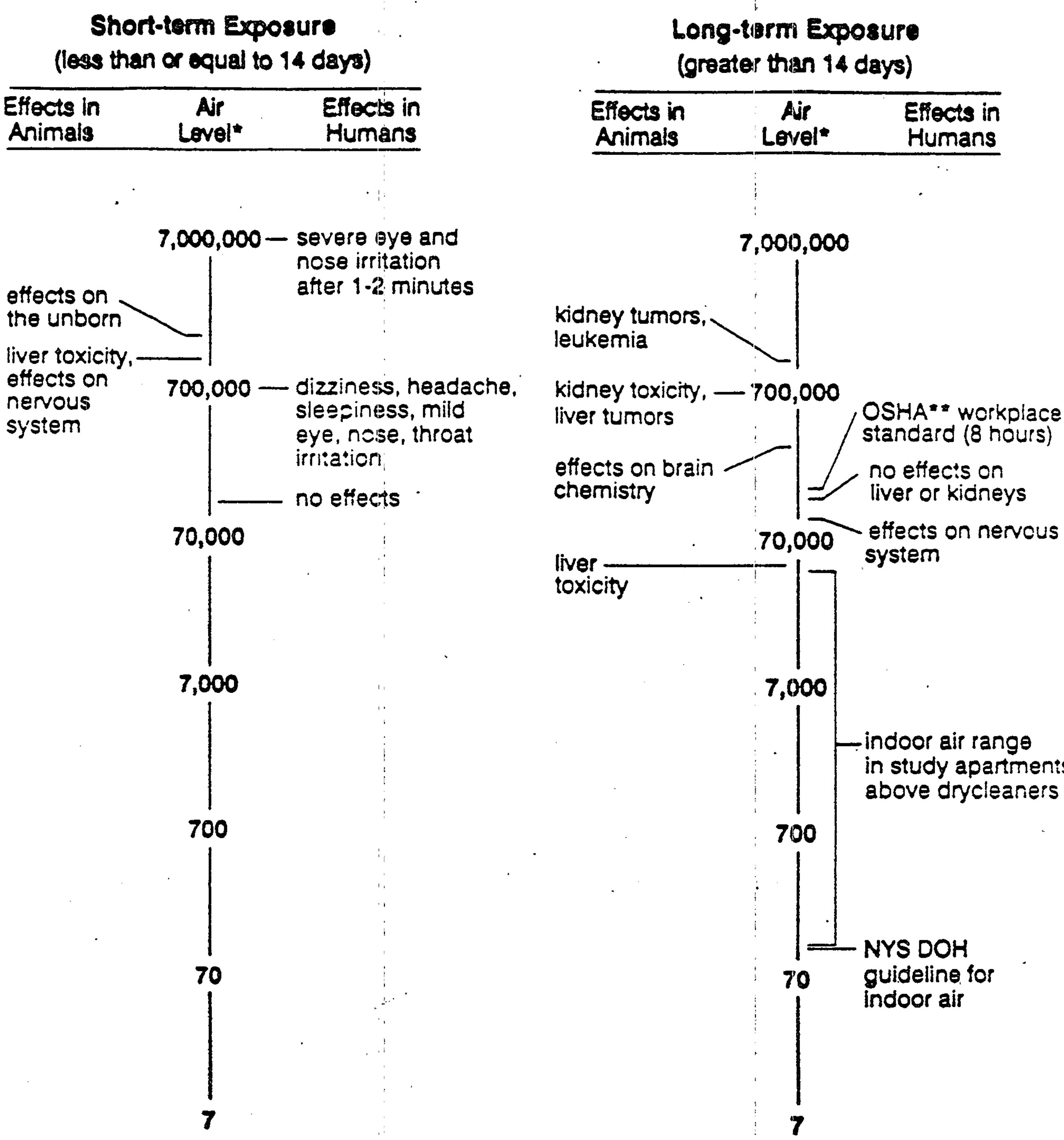
NYSDOH and NYSDEC have met with representatives of the dry cleaning industry. With their cooperation, the NYSDOH is conducting a survey of all dry cleaners in New York State to assess the different operations, building uses and types of equipment. This information will be used by local health departments to determine which dry cleaning facilities will be investigated next. The NYSDEC and industry professionals will work with dry cleaners to take steps to reduce emissions. These actions may include good housekeeping measures such as storing solvents properly and insuring that emission control equipment is working effectively. It may also include changes in building ventilation or the installation of new equipment, if necessary. The NYSDEC has prepared draft regulations to limit air emissions from dry cleaners. The regulations are designed to require proper ventilat'on and control in the dry cleaner workrooms and to reduce emissions to residential areas and outdoor air. There will be opportunity for public comment on these draft regulations when they are formally proposed later this year.

FOR FURTHER INFORMATION

If you think you are being exposed to tetrachloroethene, or if you smell odors from a dry cleaner in your area, call your local county or state health department. The telephone number is listed in the Blue Pages of your telephone book. If you are concerned about possible health effects you think may be related to tetrachloroethene exposure, consult your physician. For more information about the dry cleaners program, or for a copy of the dry cleaner study, contact the NYSDOH at 1-800-458-1158, extension 405. More information on the draft regulations on dry cleaner emissions is available from Mr. Jack Lauber of NYSDEC at 518-457-7688.

20020619

HEALTH EFFECTS FROM BREATHING TETRACHLOROETHENE***



* micrograms per cubic meter of air

** OSHA - Occupational Safety and Health Administration

*** Effects are listed at the lowest level at which they were first observed. They may also be seen at higher levels.

Submission from Elizabeth Bourque Massachusetts Department of Public Health

The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
Division of Food and Drugs
305 South Street
Jamaica Plain, Mass. 02130
(617) 727-2670

William F. Weld
Governor
David P. Forsberg
Secretary
David H. Mulligan
Commissioner

April 14, 1992

Arthur J. Beebe, Director
Northeast Region
Food and Drug Administration
One Montvale Avenue
Stoneham, MA 02180

Dear Jim:

We have experienced one recent situation where foods in storage were exposed to vapors from volatile organic chemicals and another situation where a business was proposing a convenience food store on an active hazardous waste site. In the former situation, we were not able to obtain an appropriate action level for various chemical residues in the exposed foods. In the later case, no one was able to provide any information on the degree of uptake of chemical vapors by packaged foods in the proposed store nor indicate what levels, if any, would be acceptable in the food items. Conversations with Food and Drug Administration (FDA) personnel in Washington indicated that an advisory guideline could be given if requested by a state. We are therefore, requesting an advisory guideline from FDA for tetrachloroethylene (PCE) levels in butter and/or margarine.

FDA already has performed a number of studies identifying PCE as a contaminant in food:

1. Richard C. Entz and Gregory W. Diachenko, Division of Food Chemistry and Technology, FDA, Washington, DC
Residues of Volatile Halocarbons in Margarines
1988, Food Additives and Contaminants, 5:3, 267-76.

2. Lee J. Miller and Allen D. Uhler, Division of Contaminants Chemistry, Food and Drug Administration, Washington, DC
Volatile Halocarbons in Butter: Elevated Tetrachloroethylene Levels Obtained in Close Proximity to Dry-Cleaning Establishments
1988, Bull. Environ. Contam. Toxicol. 41:469-474.

3. David L. Heikes, Food and Drug Administration, Total Diet Research Center, 1009 Cherry St., Kansas City, MO
Purge and Trap Method for Determination of Volatile Halocarbons and Carbon Disulfide in Table-Ready Foods
1987, J. Assoc. Off. Anal. Chem. 70:2, 215-226.

4. James L. Daft, Food and Drug Administration, 1009 Cherry St., Kansas City, MO
Rapid Determination of Fumigant and Industrial Chemical Residues in Food
1988, J. Assoc. Off. Anal. Chem. 71:4, 748-760.

Entz and Diachenko found levels of 500 to 5,000 ppb in margarines obtained from stores located next to a dry cleaner. In a similar manner the paper of Miller and Uhler found that:

> "butters collected from stores with no dry-cleaning establishments nearby generally contained less than 50 ppb of PCE,....However, many of the butters from stores located near dry-cleaning establishments had elevated levels of PCE (100 to greater than 1,00ppb)." p.473

In addition I have enclosed four papers from Germany on the contamination of foodstuffs by PCE:

1. Stefan Vieths, Werner Blaas, Manfred Fischer, Christian Krause, Irena Mehlitz, Rudolf Weber and Max von Pettenkofer, Institute of the Federal Department of Health; Institute for Clean Water, Soil, and Air of the Federal Department of Health, D-1000 Berlin 33
   Contamination of Foodstuffs via the Gaseous Phase by Tetrachloroethylene Emissions of a Dry Cleaning Establishment
   1987, Z Lebensm Unters Forsch 185:267-270.

2. Stefan Vieths, Werner Blaas, Manfred Fishcer, Christian Krause, Reinhard Matissek, Irena Mehlitz and Rudolf Weber, Max von Pettenkofer Institute of the Federal Department of Health, Institute of Water, Soil, and Air Quality of the Federal Department of Health; Institute of Food Chemistry of the Technical University of Berlin
   Contamination of Foodstuffs by Emissions from Dry Cleaning Establishments
   1988, Z Lebensm Unters Forsch 186:393-397.

3. K. Reinhard, W. Dulson and M. Exner, Institute for Environmental Studies of the Office of Environmental Protection of the City of Cologne; Public Health Institute of the Ruhr Area, Gelsenkirchen
   Investigations of the Presence of Tetrachloroethylene in Indoor Air and Food in Dwellings in the Vicinity of Dry Cleaning Shops
   1989, Zbl Hgy. 189: 111-116.

4. J. Shaefer and H. Hohmann, Principal Public Health Officer
   Tetrachloroethylene Pollution of Residents Adjacent to Dry Cleaners
   1989, Off Gensundh-Wes 51:291-295.

As described in the above papers, in 1989 Germany propagated a PCE guiding value of 100 micrograms per kilogram of food.

Considering the problems that contamination of foodstuffs by PCE causes, I hope that FDA will be able to provide us with an advisory guideline for butter and/or margarine.

Sincerely,

Richard D. Waskiewicz (EAB)

Richard D. Waskiewicz, M.S.
Deputy Director
Division of Food and Drugs

NR:rw:eab
181:dryclea1

IMPORT ALERT

ORO/DFI (HFC-131)
IMPORT OPERATIONS

Perchloroethylene (PCE) And Trichloroethylene (TCE) Residue In Olive Oil

No.: 26 - 03

Date: August 17, 1988

TYPE OF ALERT: Surveillance

PRODUCT : Olive Oil, Virgin Grades or Cold Pressed Grades

PROBLEM : Perchloroethylene (PCE) and Trichloroethylene (TCE)

COUNTRY : All Countries

MANUFACTURER/ SHIPPER : All

CHARGE : "The article is subject to refusal of admission pursuant to Section 801 (a)(3) because it appears to be adulterated under Section 402 (a)(2)(C) in that it contains the food additive, perchloroethylene (and/or trichloroethylene), which is unsafe within the meaning of section 409".

RECOMMENDING OFFICE : HFC-131

REASON FOR ALERT : On April 28, 1988, Import Operations Branch issued an Import Bulletin (26B-01) advising districts of reported findings of PCE or TCE in olive oil by the U.S.D.O.D. and the Government of the Federal Republic of Germany.

On May 2, 1988, ORA issued an assignment to sample shipments of all grades of olive oil. Approximately 160 samples of olive oil were sampled and examined. Levels reported ranged from none (<50 ppb) to 956 ppb with 37 samples containing detectable levels. Trichloroethylene (TCE) was also reported in 7 samples at levels up to 891 ppb. No PCE or TCE was found in three domestically produced olive oil samples tested.

Subsequent review of the findings by CFSAN toxicologists concluded that the levels found should not pose a hazard to the public health. However, in July, 1988, FDA received information from Italy, Spain, France, and Germany which suggests that the industrial solvents, PCE and TCE, are being used in a food additive context in one or more of those countries and that these uses are the source of these substances in the olive oil from those countries. Reported possible uses include putting PCE contaminated olives into the regular production, following extraction of those olives with

PCE to test for oil content in the Foss-Let test and use as a solvent for degreasing and cleaning tanks, harvesting nets or other equipment in the plant. In view of this information, the agency is now viewing the PCE and TCE residues in olive oil as unsafe food additives.

Residues were found in the product from many countries. Much of the olive oil from other countries is reportedly produced in Spain, and the bulk of reported residues are in product manufactured in Spain. However, since these products are frequently transshipped, we have no basis for excluding product from any country from the alert. The substances are reportedly found in virgin or cold pressed grades of olive oil. Refining apparently removes the substances.

INSTRUCTIONS : Detain olive oil in import status found to contain over 50 ppb PCE or TCE.

FOI : No purging required.

Submission from Walther den Otter TNO Cleaning Techniques Research Institute

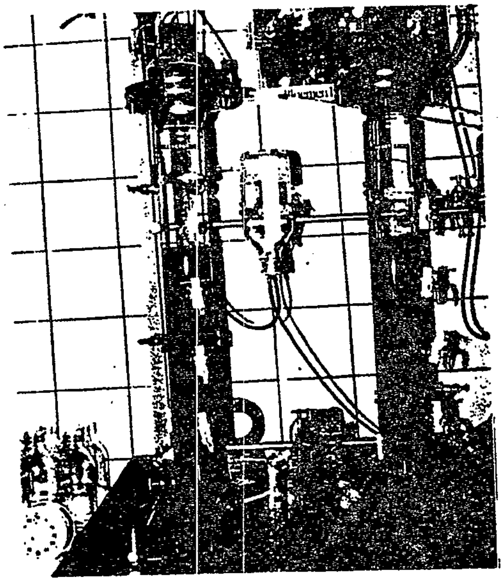
Biorestoration of soils and groundwater contaminated by chlorinated ethylenes

Chlorinated organic solvents as tetrachloroethylene (PCE) and trichloroethylene (TCE) are widely used for dry cleaning and in other industrial degreasing processes. Due to accidental spillage many sites all over the world have been contaminated with these persistent organic compounds. In soil and groundwater PCE and TCE are degraded very slowly or not at all. Biotechnological in-situ treatment is an acttractive alternative for remediation. TNO has developed such a biotechnological process.
The treatment method consist of a two-stage process. By creating the right anoxic conditions, PCE (and TCE) can be dehalogenated (Table 1). In the second, aerated stage the remaining TCE and the dichloroethylenes are completely mineralized by a microbial co-oxidation process. The technology can be applied for on site treatment and in situ bioremediation.

Table 1 Concentrations (µg/l) of chloroethylenes in the effluent of anoxic reactors fed with groundwater contaminated with tetrachloroethylene. Tests were performed using 5 laboratory scale reactors of 2.5 liter working volume.

reactor	In PCE	Out PCE	Out TCE	Out 1,2 cis[1]	Out 1,2 trans[1]
A	573	<1	19	88	245
B	506	<1	27	101	143
C	370	<1	151	86	44
D	388	<1	5	75	207
E	442	<1	6	108	36

[1] 1,2 cis/trans dichloroethylene



The application of bioremediation should always start with:
1. A description of the local geohydrological circumstances.
2. A test programm for defining the conditions (temperature, nutrient requirement) by which the chloroethylenes degrading microorganisms at that particular site can be stimulated.

The Netherlands organization for applied scientific research (TNO) has the experience and the facilities to further develop the method to pilot scale. For further information, please contact:
Dr. H. Doddema
TNO Institute of Environmental Sciences
Department of Environmental Biotechnology
P.O. Box 6011
2600 JA Delft, The Netherlands
Fax: +31 15 616812
Phone: +31 15 696022

Submissions from Joseph Kurz Institute Hohenstein

27. / 28.05.1992

Prepared for Discusssion

Ground Water Protection

EPA68 KU

EPA Roundtable	**Josef Kurz**	Institute Hohenstein

Survey

Ground Water Protection

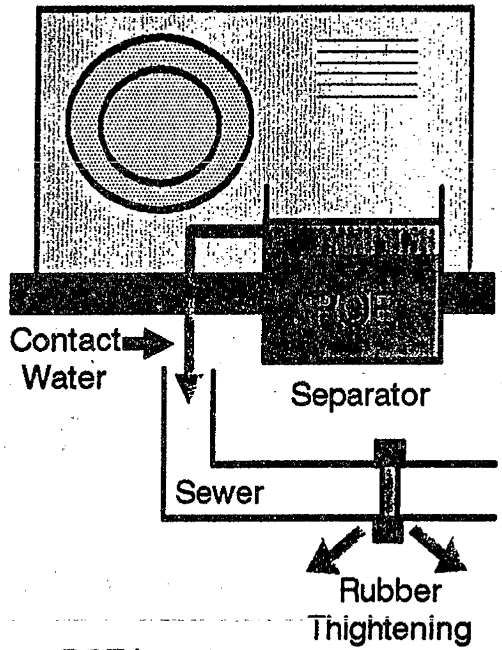
1.1. Sources of Contamination
1.2. Contamination
2. Degree of Contamination
3. Avoidance of Contamination
4.1. Contaminated Water
4.2. Storage of Barrels
4.3. Storage of Containers
4.4. Storage in Machine
5. Purification Procedures
6. Purification by Adsorption
7. Field Tests
8. Controlling after Purification
9. Purification of Contaminated Ground and Ground Water
10. Progress of Decontamination

EPA 25 KU

EPA Roundtable	Josef Kurz	Institute Hohenstein

1.1. Sources of Contamination

Drain



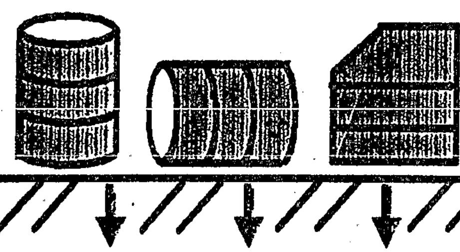
PCE in water:
160 to 500 mg/liter

Handling

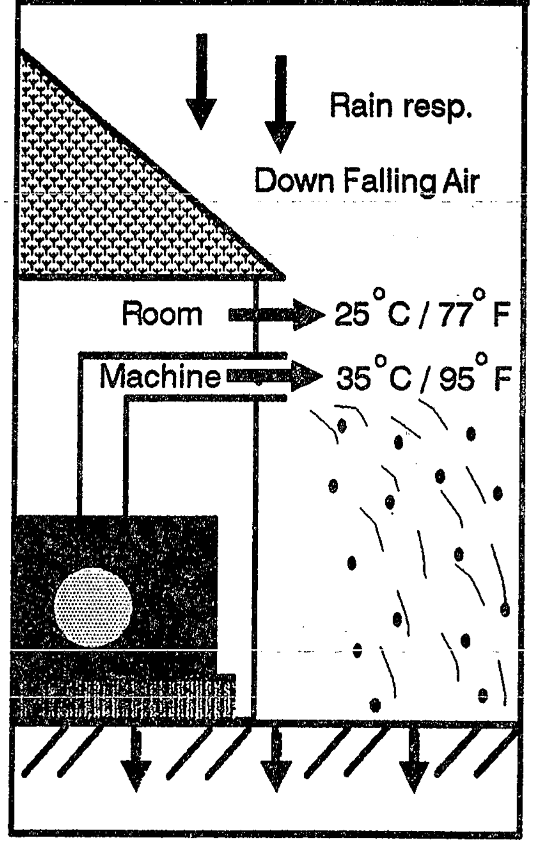
- Careless handling when filling the machine, when emptying the button trap
- Leaks of tightenings, gaskets packing rings etc.

Storage

Fresh solvent, detergents, aids, destillation residues



Deposit



EPA 13 KU

EPA Roundtable | **Ground Water Protection** | Institute Hohenstein

1.2. Contamination

Threshold value for drinking water:

25 μg chlorinated hydrocarbons = 25 μg perchloroethylene

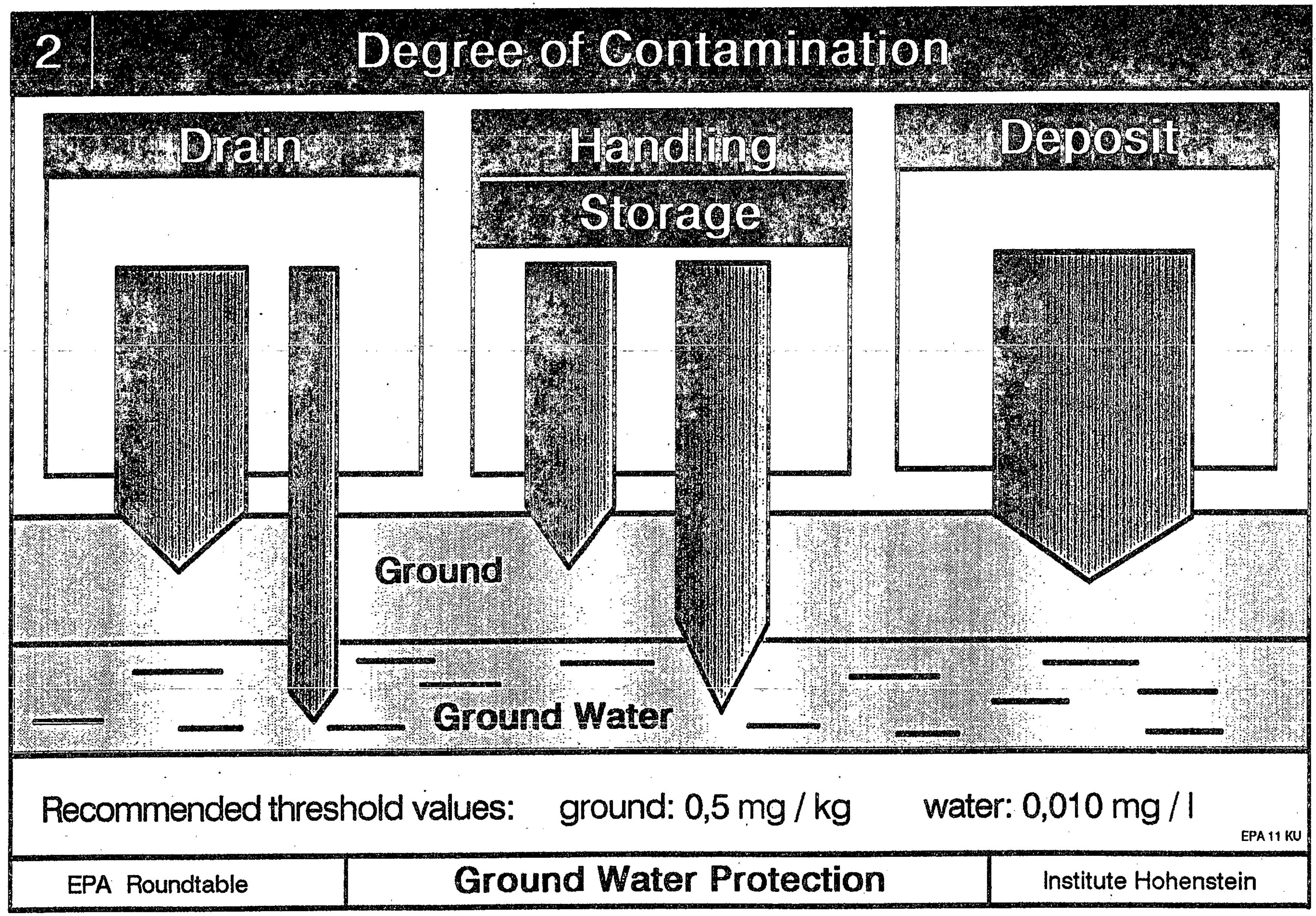
Example
PCE:

1 mg	= 1000 μg	= 40 liter / 25 μg
1 g	= 1000 mg	= 40 000 liter / 25 μg
1 kg	= 1000 g	= 40 000 000 liter / 25 μg
1 liter	= 1600 g	= 64 000 000 liter / 25 μg
	= 1,6 kg	= 64 000 m^3

Water Consumption of 1 person per day = 200 liter

$1\ m^3$ = 5 persons
$64\,000\ m^3 \times 5$ = 320 000 persons

EPA 19 KU


2
Degree of Contamination
Drain
Handling
Storage
Deposit
Ground
Ground Water
Recommended threshold values: ground: 0,5 mg / kg water: 0,010 mg / l
EPA 11 KU
EPA Roundtable
Ground Water Protection
Institute Hohenstein

3 Avoidance of Contamination (Overview)

Drain

Purification of contaminated water of the water separator by
- adsorption,
- stripping,
- absorption.

Threshold value: 0,5 mg PCE per liter water

Regulation
- Law on Water Protection

Handling

Carefully!

Storage

Storage of solvent and solvent containing detergents /aids and destillation residues in a safety trough

Regulations
- Regulation on Clean Air
- Law on Water Protection

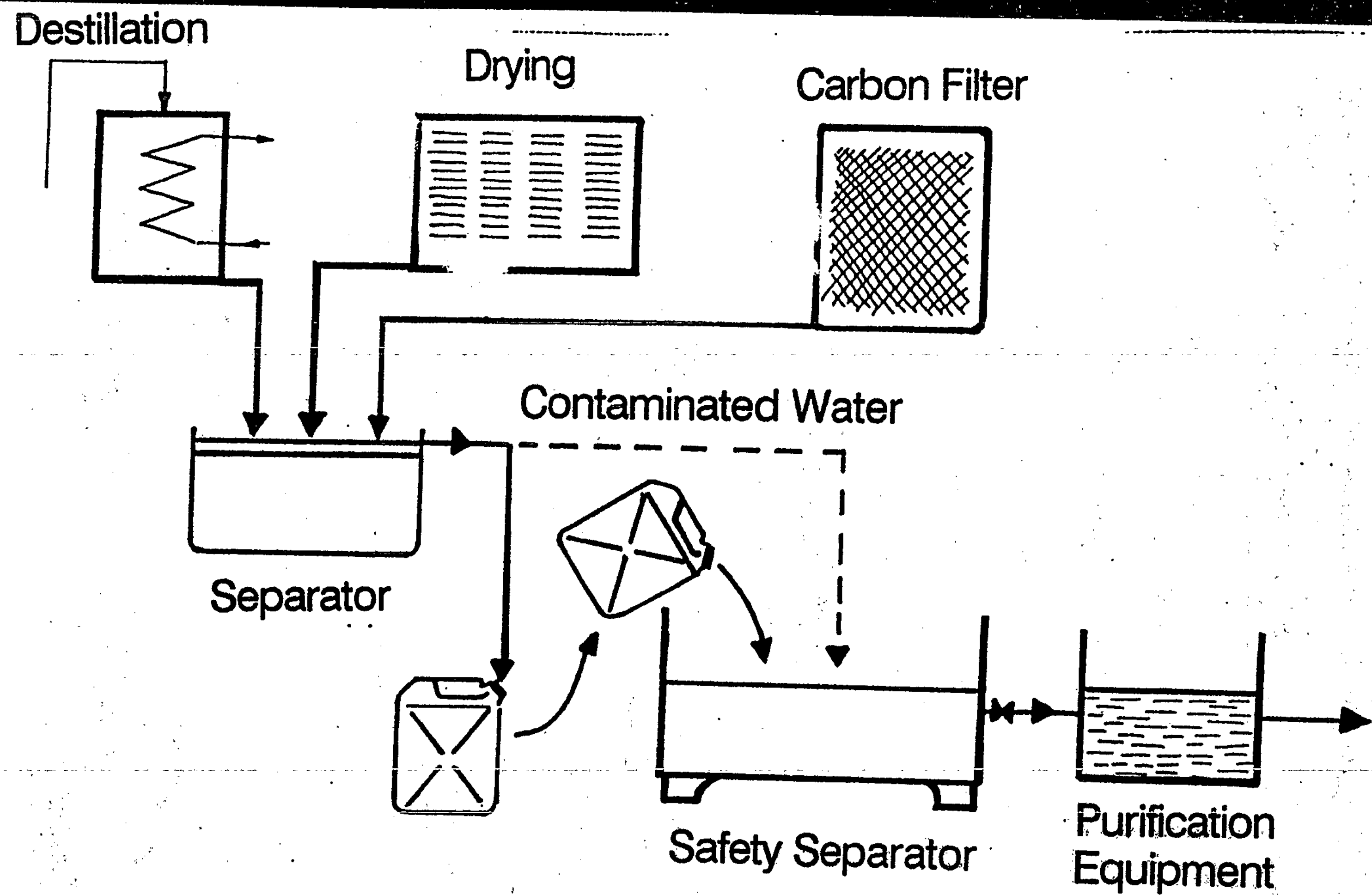
Deposit

- Outlet air of exhausting machines not higher than 20 mg PCE / m^3 (~ 3 ppm)
- Outlet air from the workroom less than 35 mg PCE / m^3 (~ 5 ppm)

Regulations
- Regulation on Clean Air
- Regulation of German OSHA

EPA 24 KU

4.1. Contaminated Water

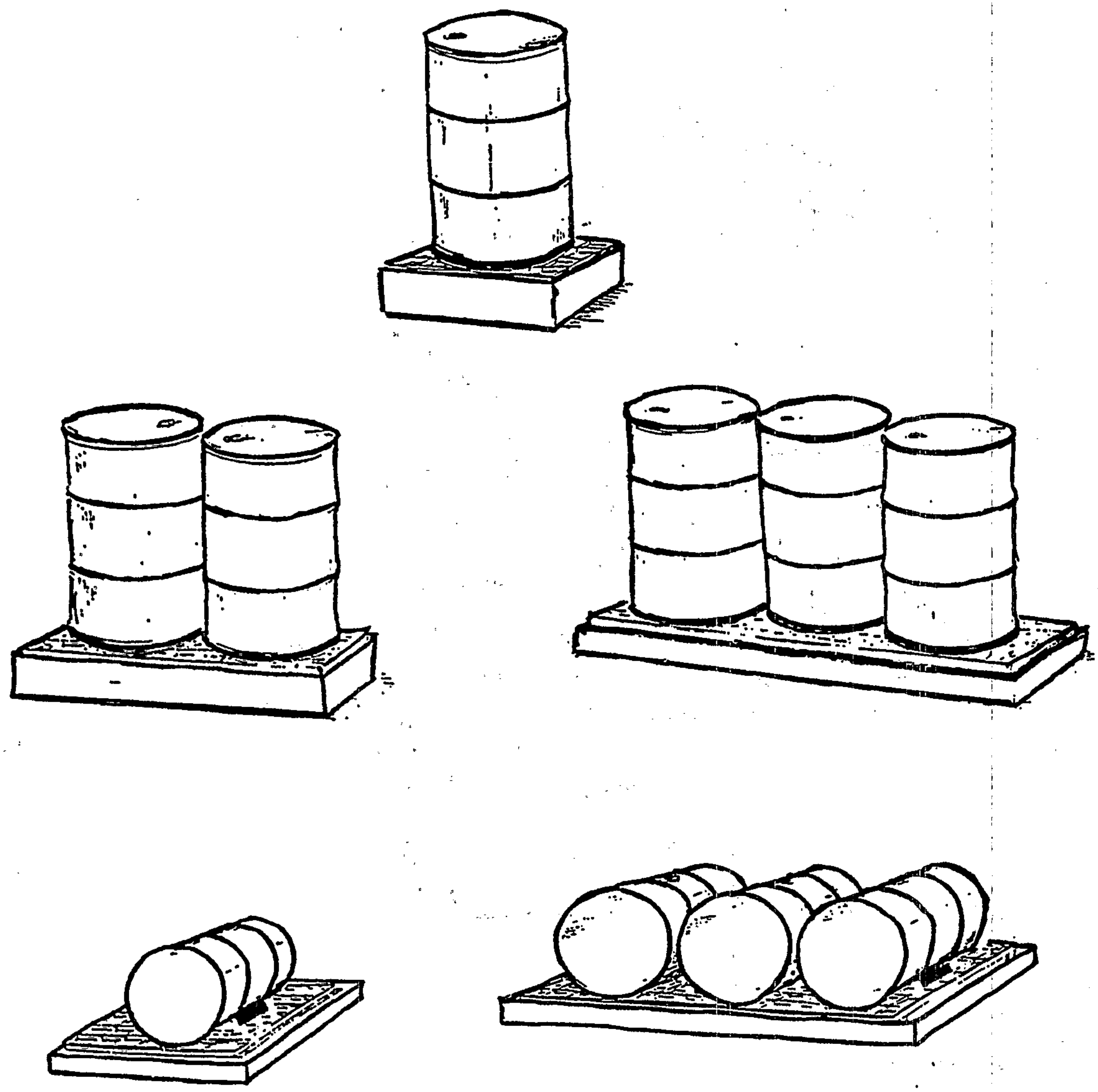


EPA 27 KU

4.2. Storage

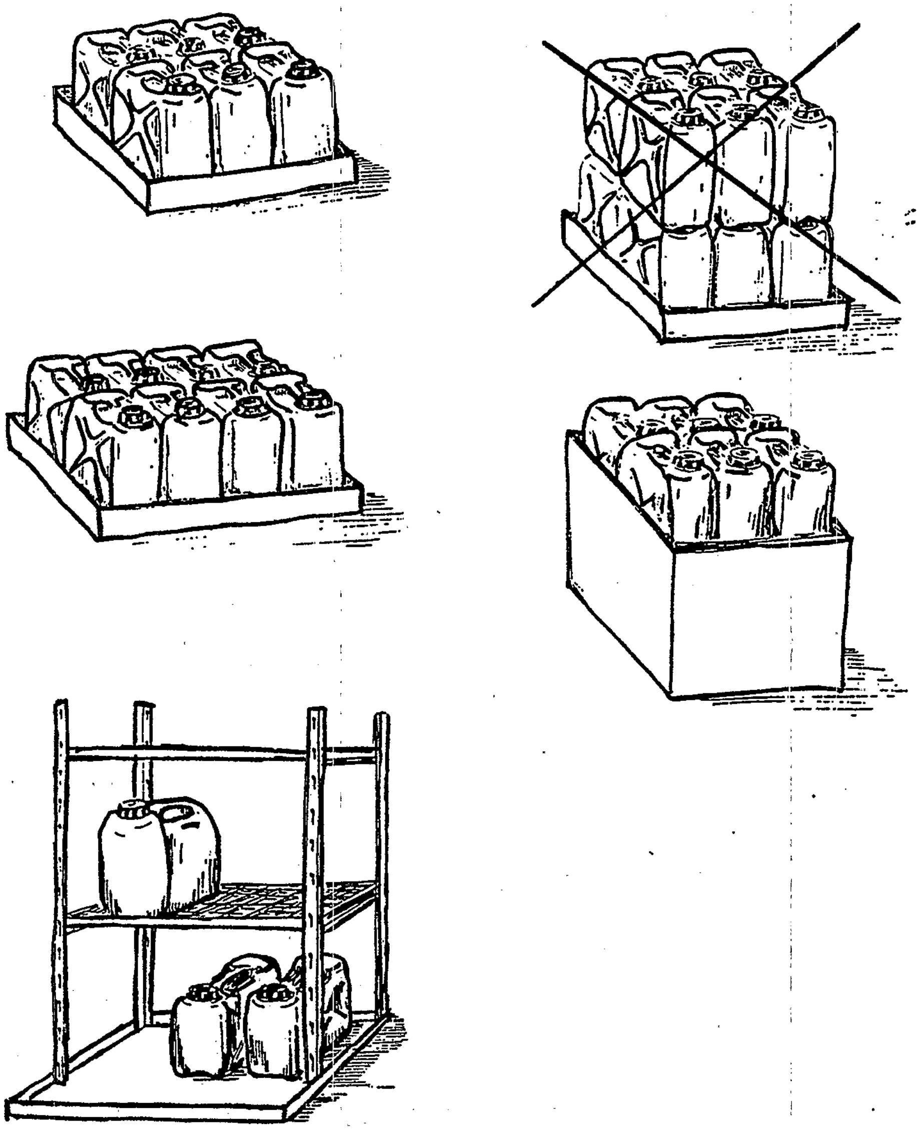
Collecting Volume of Safety Troughs

200 liter = volume of one barrel



(EPA 52KU)

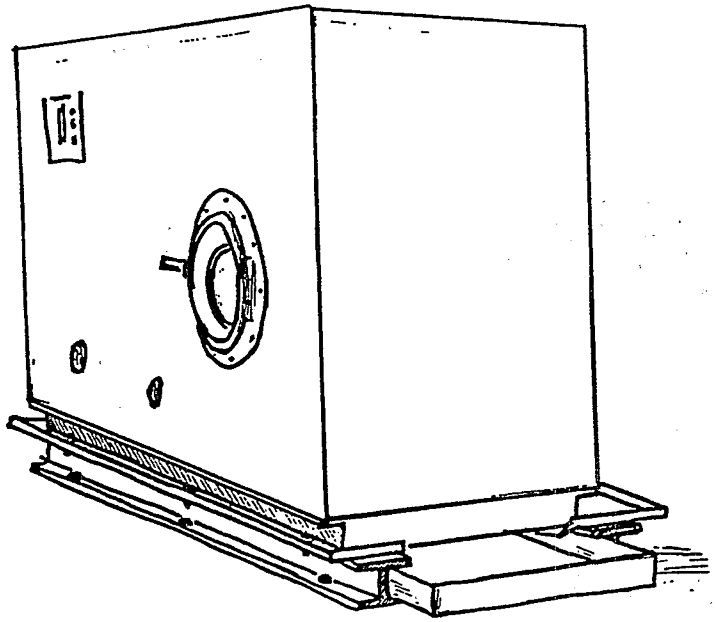
4.3. Storage

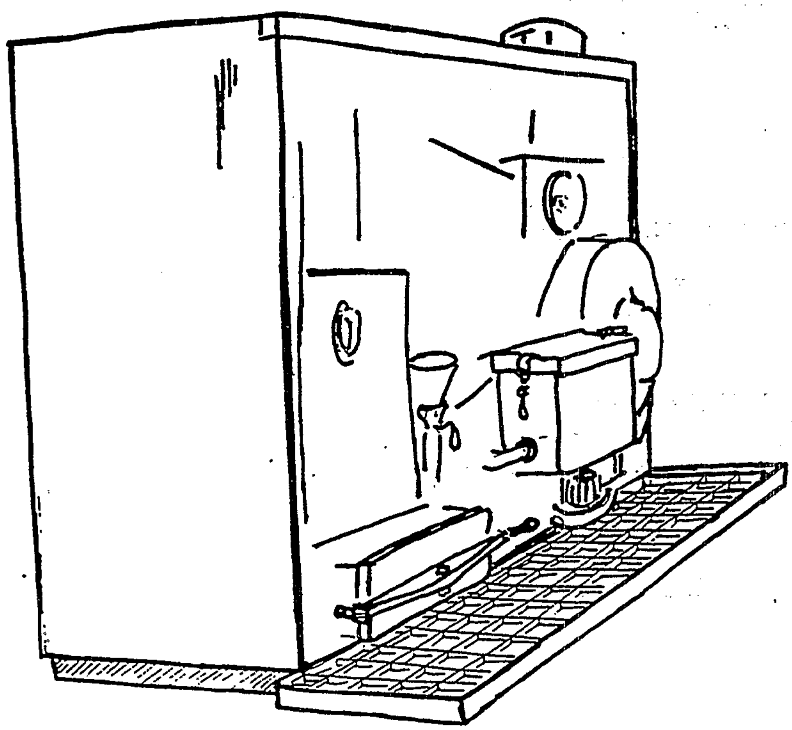


(EPA 52KU)

EPA Roundtable	**Ground Water Protection**	Institute Hohenstein

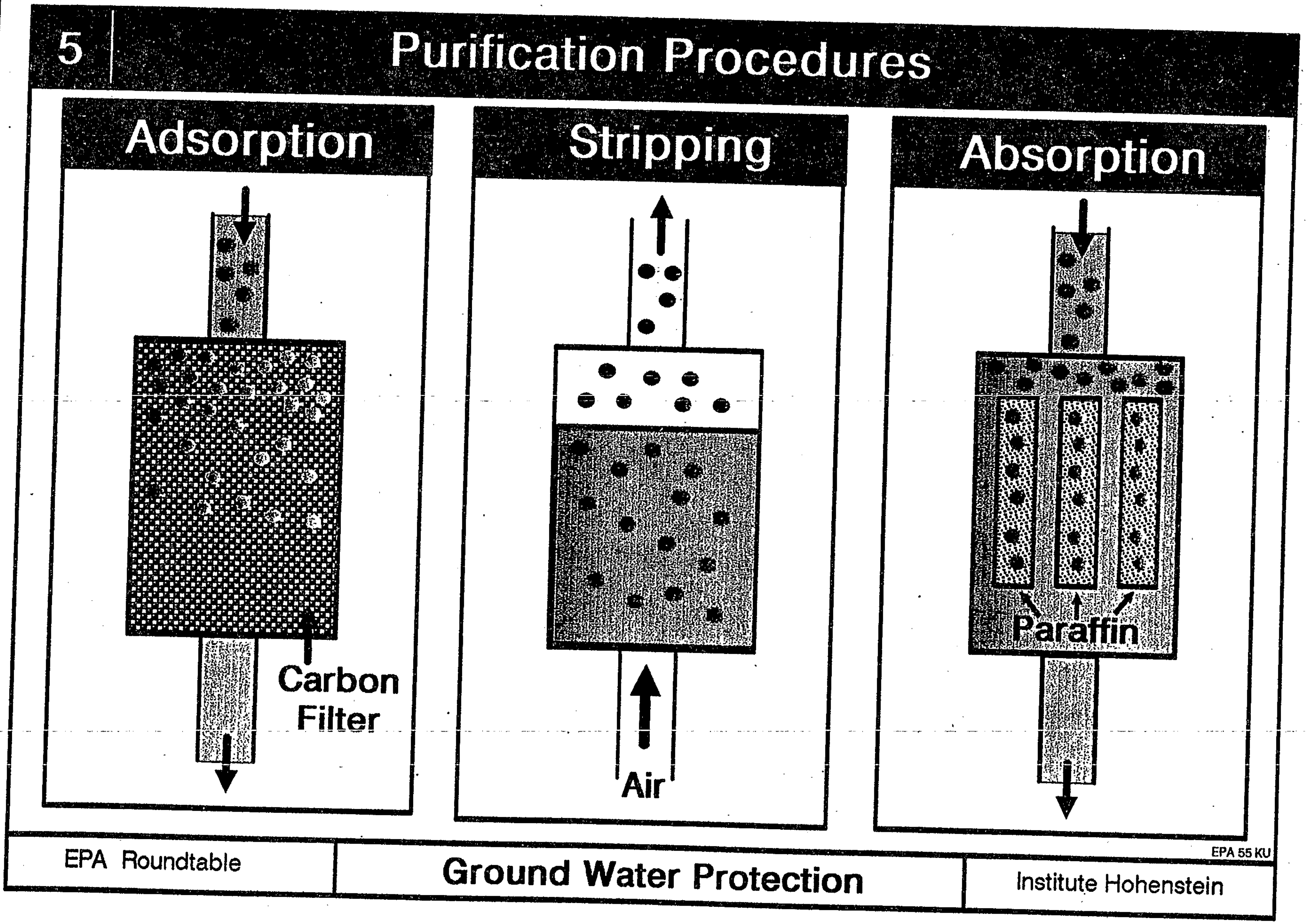
4.4. Storage in Machine

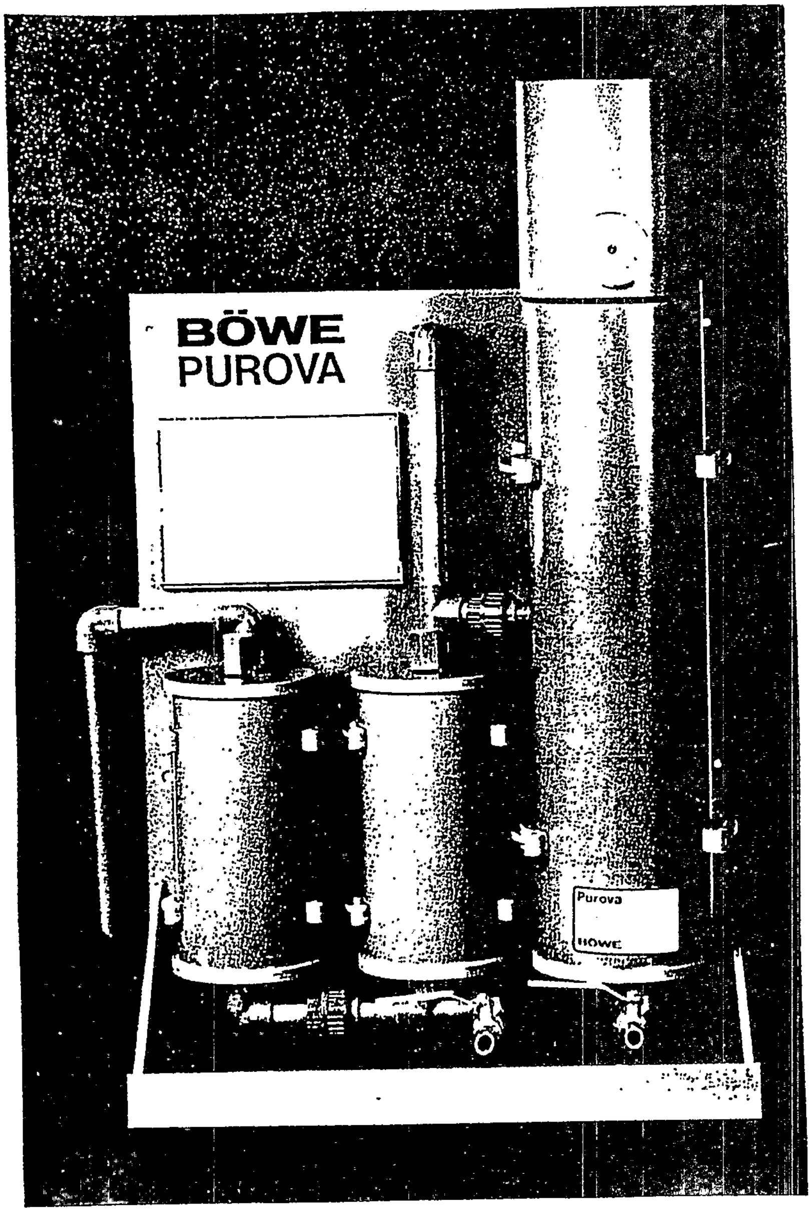




(EPA 53KU)

EPA Roundtable	**Ground Water Protection**	Institute Hohenstein

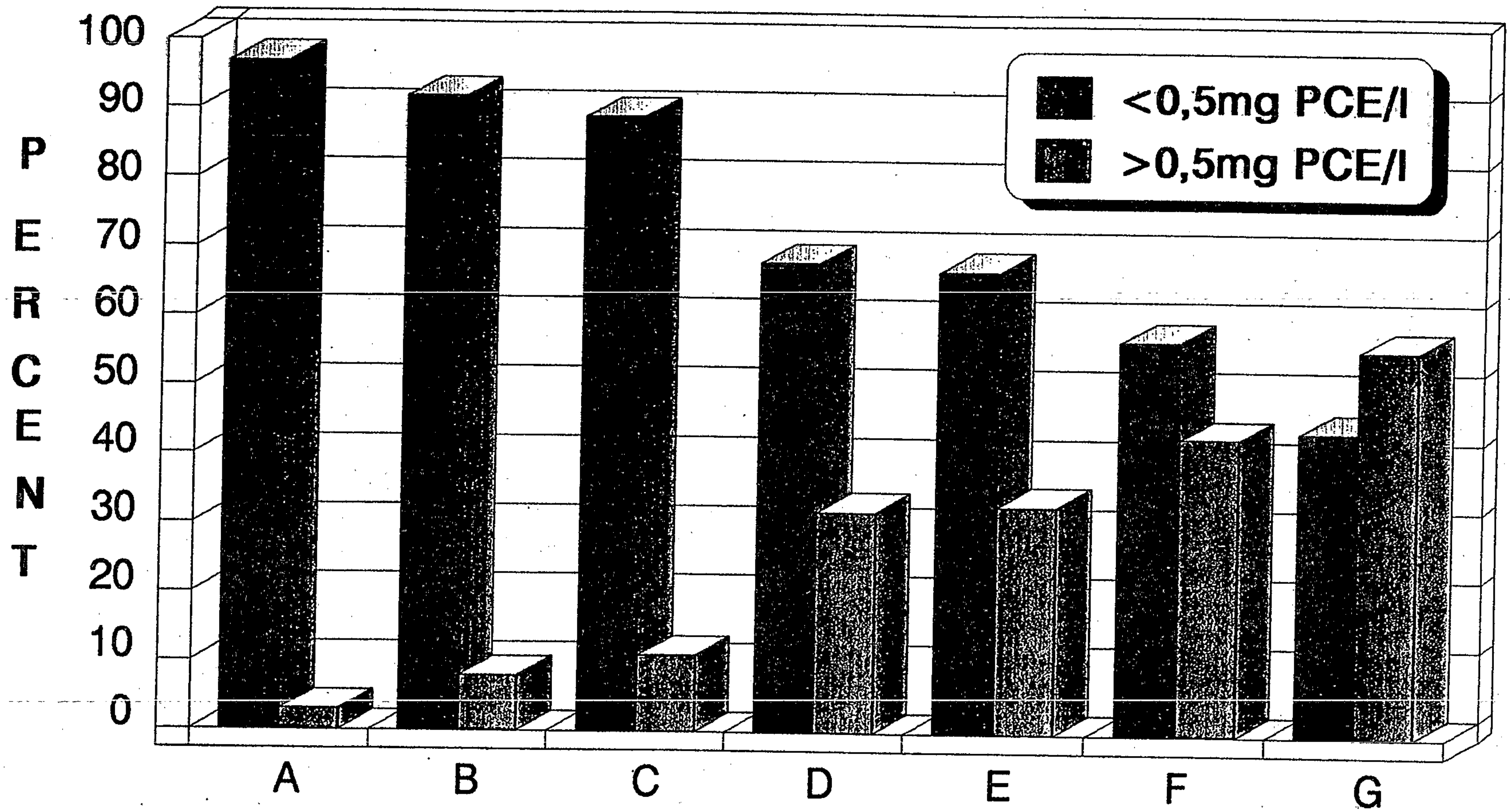

5
Purification Procedures
Adsorption
Carbon
Filter
Stripping
Air
Absorption
Paraffin
EPA Roundtable
Ground Water Protection
Institute Hohenstein
EPA 55 KU



Purification device for 5 liter per day
Sizes: 70 cm x 54 cm x 30 cm

(EPA 21KU)

7 Field Tests

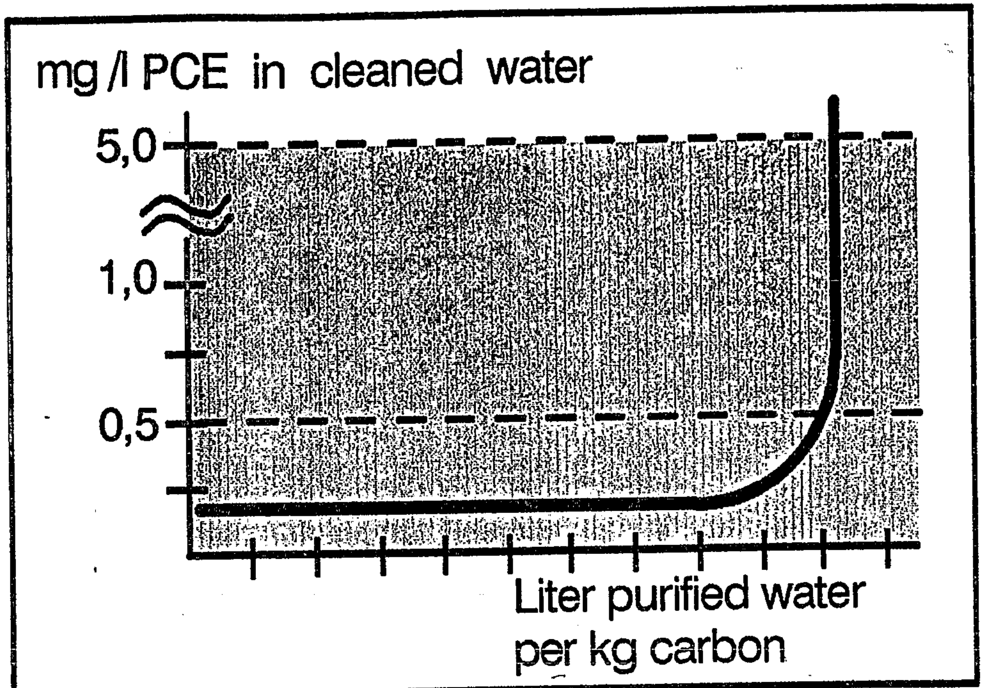


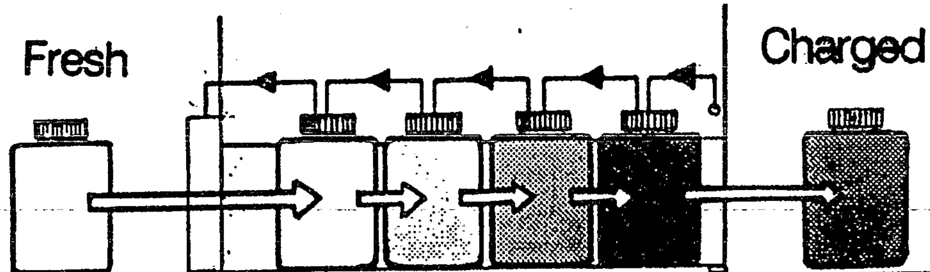
A to G = Type of contact water treatment device.

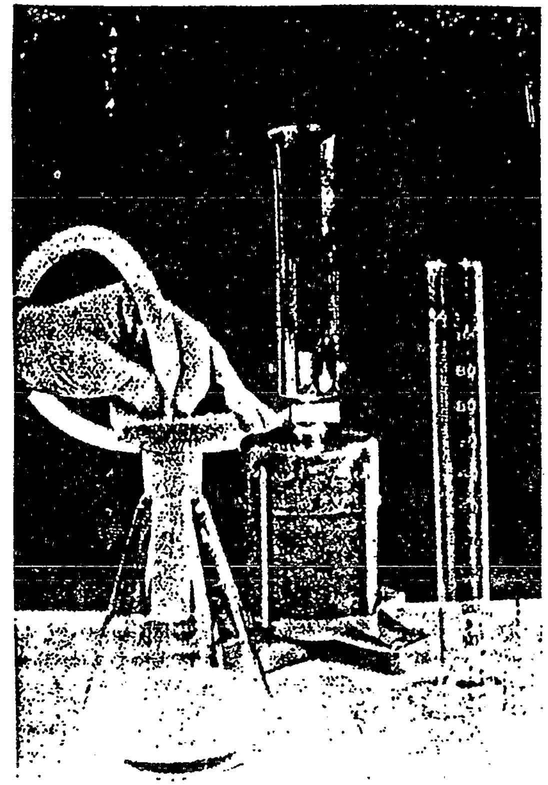
EPA 22 KU

EPA Roundtable	**Ground Water Protection**	Institute Hohenstein

8 Controlling after Purification





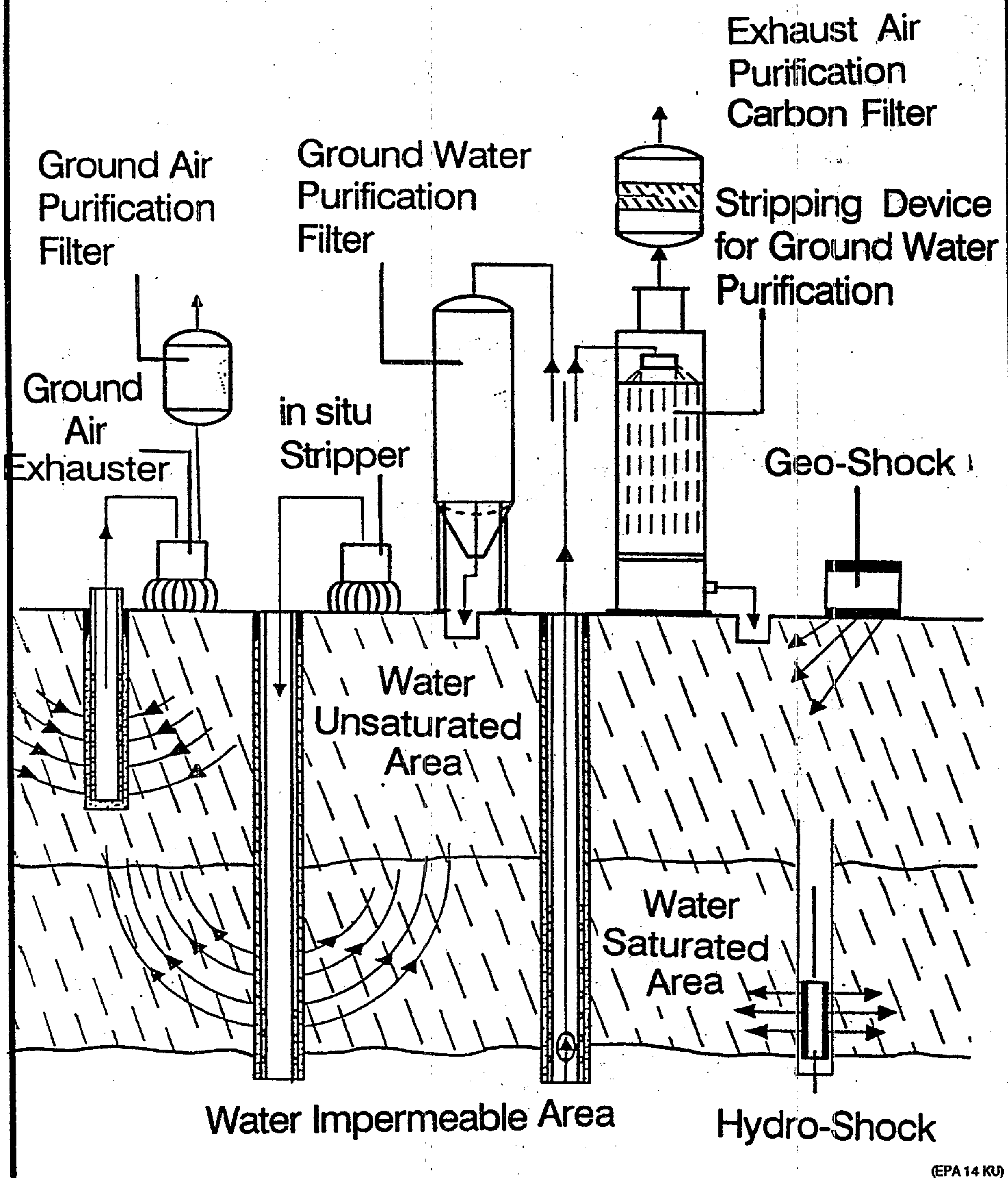


Simple Test Method

EPA 23 KU

EPA Roundtable	**Ground Water Protection**	Institute Hohenstein

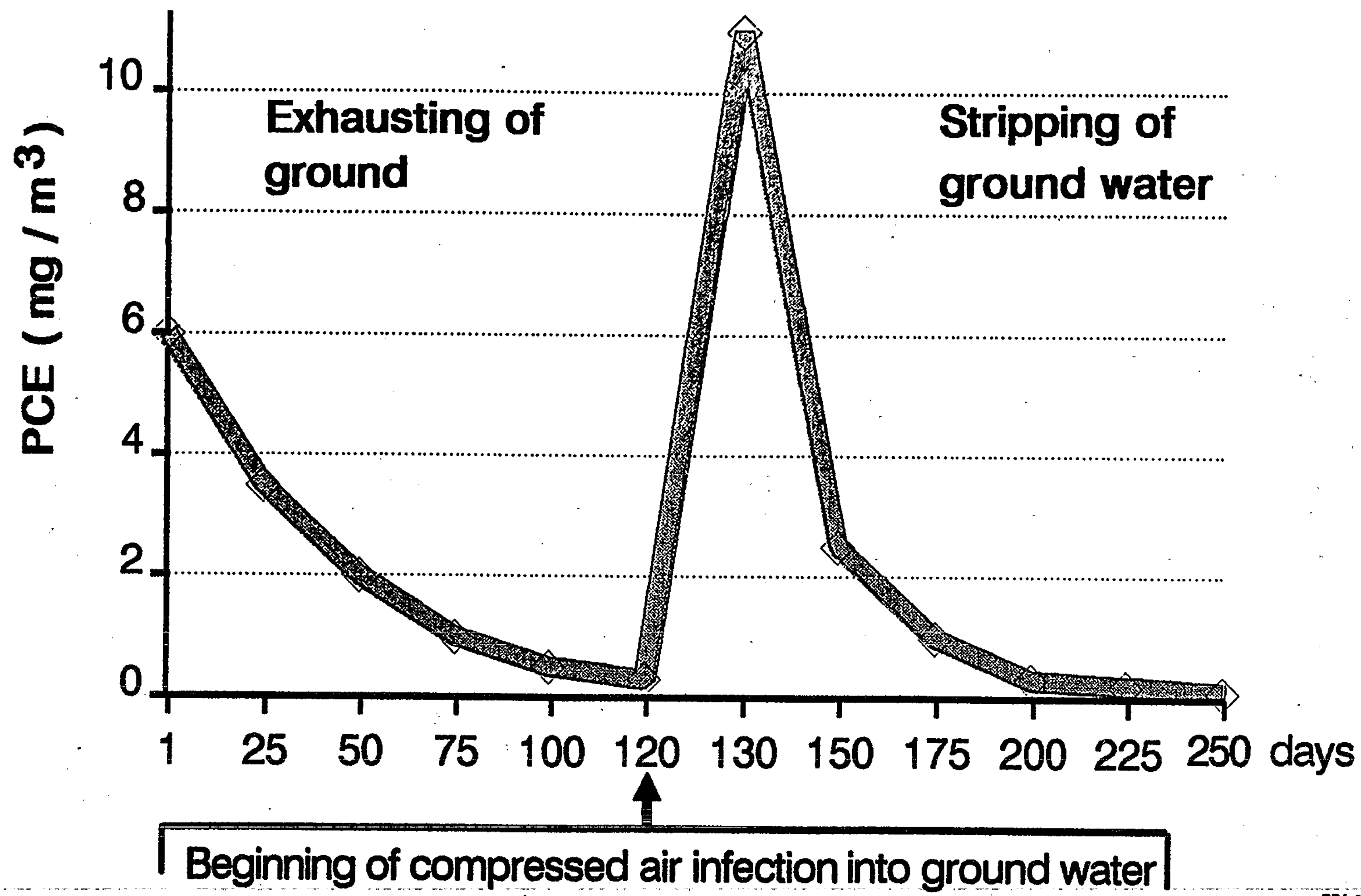
9 Purification of Contaminated Ground and Ground Water



Ground Water Protection

10

Progress of Decontamination



EPA 26 KU

EPA Roundtable | **Ground Water Protection** | Institute Hohenstein

Prepared for Discussion

Resident Exposure Reduction

EPA54 KU

Survey

Resident Exposure Reduction

1. Definition of the Problem
2. Diffusion Barrier
3. Test: Perchloroethylene in Appartment Buildings
4. Diffusion Barrier
5. Diffusion Inhibiting
6. Diffusion Barrier
7. Prevention
8. PCE Levels in Residential Areas

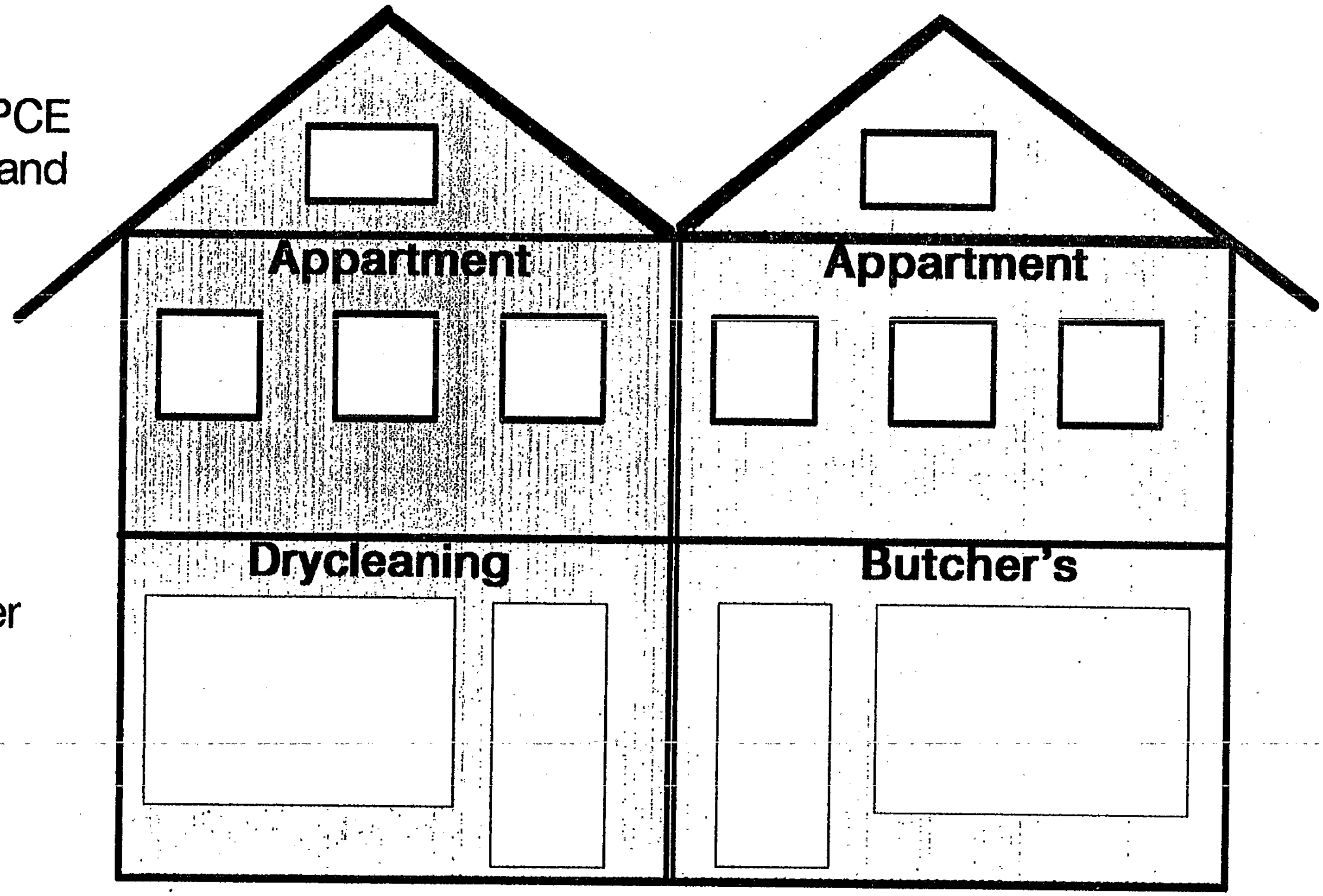
EPA35 KU

1

Definition of the Problem

Problem:

- Diffusion of PCE through walls and ceilings



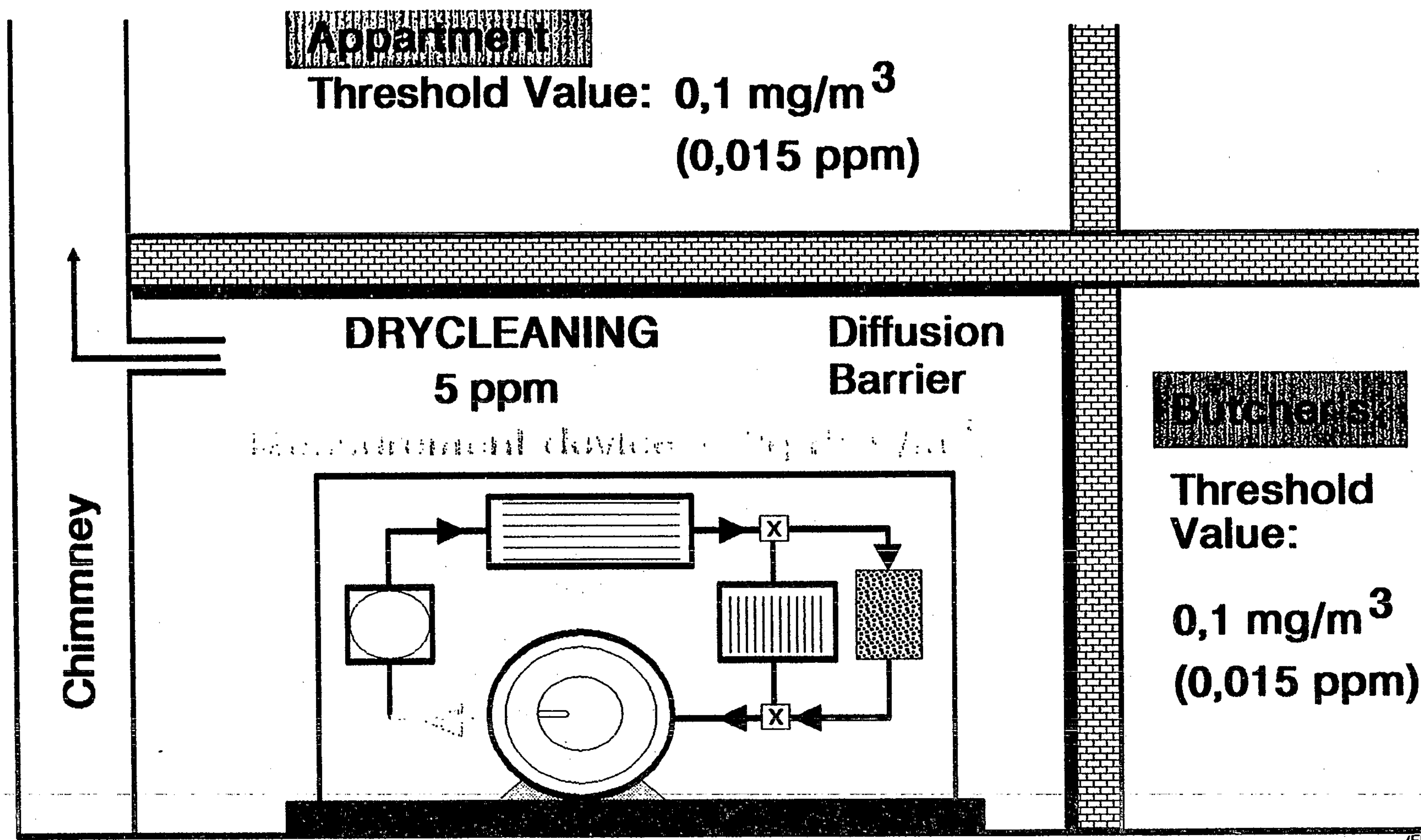
- Avoidance

Diffusion barrier on walls and ceilings.

(EPA62 KU)

2

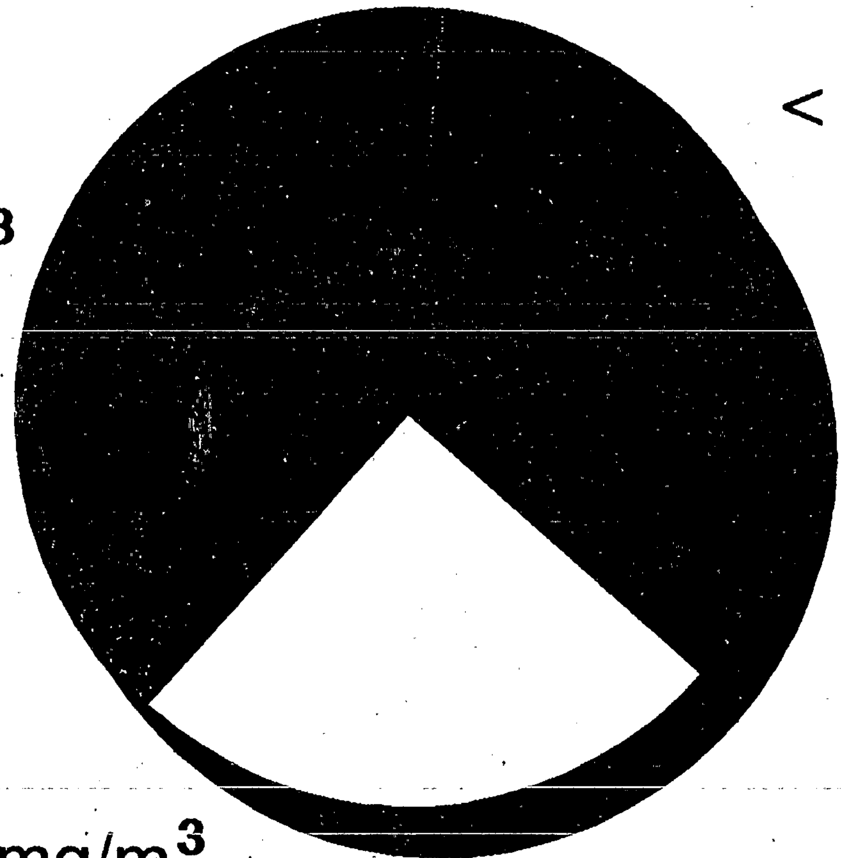
Diffusion Barrier



3

Test: Perchloroethylen in Appartment Buildings

4/'91 - 5/'92

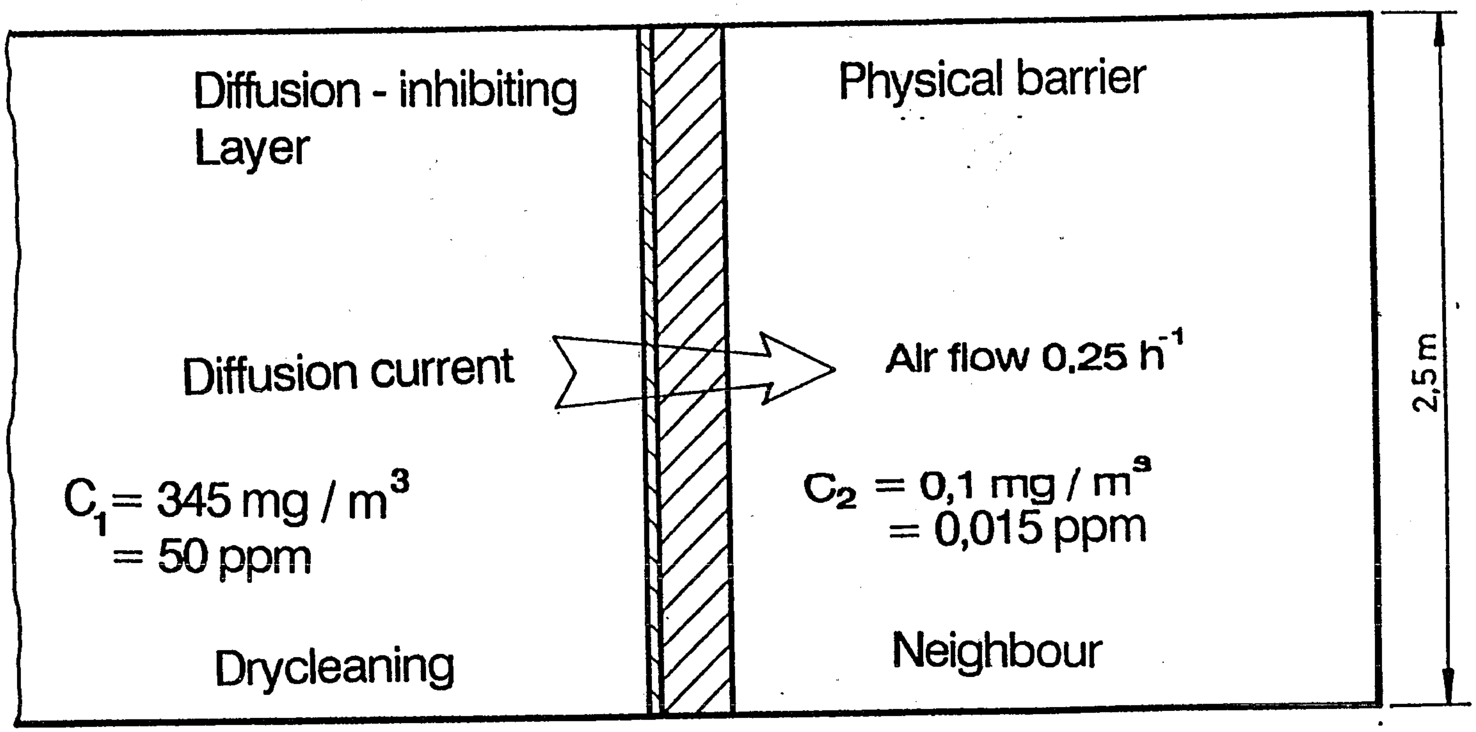


(EPA32 Pi)

EPA Roundtable	**Resident Exposure Reduction**	Institute Hohenstein

4

Diffusion Barrier



(EPA42 Pi)

5

Diffusion Inhibiting

Necessary thickness of walls to inhibit contamination of a neighbouring room higher than 0,1 mg/m^3.

Building Material	Diffusion Coefficient δ	Necessary Thickness (in/cm)
Brick	160	> 25,6 / 65
Aearated Concrete	150	> 236,2 / 600
Interior Plaster	150	> 236,2 / 600
Lime Sandstone	80	> 137,8 / 350
Concrete	10	> 15,7 / 40

EPA71 KU

6

Diffusion Barriers

Diffusion-inhibiting layer	Diffusion Coefficient Δ	Diffusion-inhibiting effect sufficient?
Paint on a polyurethane basis	< 5	yes
Metal-containing paint on a polyurethane basis	> 175	no
Paint on a polyurethylene basis	> 5000	no
Water-soluble paint on a mineral basis	< 10	yes
Woodchip paper, butt joint overlap with plastic adhesive	< 15	yes
Woodchip paper, butt joint overlap with resin adhesive	< 10	yes
Insulating wallpaper, butt joint overlap with paste	< 25	yes

EPA72 KU

7

Prevention

1. Ventilation of the work room

2. Exhausting of the PCE- containing steam / air coming out of the finishing equipments.

- Alternatives in discussion:

  Aeration of cleaned garments in a box during and adsorption of PCE with activated carbon.

3. Measurement device in the outlet air of closed circuit machines to ensure the threshold value of 2 g / m^3 in order to minimize the transport of PCE by textiles into the workroom.

4. Barrier to prevent diffusion through walls and ceilings.

EPA29 KU

8

PCE Levels in Residential Areas

Residential Rooms

Emissions from Drycleanings

Threshold value = 0,1 mg PCE /m^3(0,015 ppm)

Maximum PCE freight per week (7days) in respiration air of an adult resident:

- Volume per respiration = 0,5 liter
- Respiration frequence = 16 times / minute
- Respiration volume = 16 x 0,5

= 8 liter / minute x 60

= 480 ~ 500 liter/hour x 24

= 12 m^3/ day x 7

= 84 m^3 / week x 0,1

= 8,4 mg PCE in 7days

Comparison : Employees in drycleaning

Threshold value: 345 mg PCE/ m^3(50 ppm)

- Respiration volume = 0,5 (liter) x 16 (frequence) x 60 (hour) x 8 (day) x 5 (week) x 345

=6900 mg PCE in 5 days

Conclusion: The relation between residential exposure value and employees exposure is about 1:1000. According to present knowledge there is no danger to health of residents and employees.

EPA53 KU

Prepared for Discusssion

Prevention of Emissions

EPA70 KU

Survey

Prevention of Emissions

1. Classification
2. Regulations
3. Regulations (continued)
4. Perchloroethylene in Work Rooms

5.1. Leakage Check, daily
5.2. Recordings
5.3. Handling

****

Charts already given in the presentation and discussion contribution

- Check of the Carbon Filter, daily
- Recordings
- Check of the Contact Water Purification, weekly
- Recordings
- Check of the Machine by an Expert, yearly
- Test of the Measurement Device Calibration, yearly
- Training of the Employees
- General Recordings

EPA75 KU

1

Classification

Occupational Exposive Limit (OEL):

Limitations laid down by a public scientific committee (German SAB):

Perchloroethylene 50 ppm

Cercinogen Substances:

III. A. Clear evidence (no OEL)

A.1 = According to experience in humans

A.2 = According to experience with animals, but under similar conditions as the exposition of humans

III. B Well-founded suspicion of cercinogenic potential.
More research work must be done to decide whether or not.
(Perchlorethylene since 1988)
Substances in this classification has OEL

(EPA28 Pl)

2

Regulations

OEL Perchloroethylene

50 ppm (=345 mg/m^3)

Definition

No danger to health, if 50 ppm is reliably not exceeded (exceptions: short - term exceedings)

1. Reliably not exceeded means:

continuous measuring with a technical device

2. In all other cases

- 3 measurements within 3 months:

  12,5 ppm (86 mg/m^3) when measured discontinuously i.e. test tubes (=threshold for the beginning of danger)

- 1 measurement a year:

  5 ppm (= 34 mg/m^3)

(EPA30 Pi)

3 *Regulations (continued)*

[redacted]

The real threshold value for perchloroethylen in drycleaning is

In case of doubt: Measurement of the concentration by our authorized institute i.e. Institute Hohenstein

[redacted]

If the OEL is kept within the limit - normally 5 ppm -

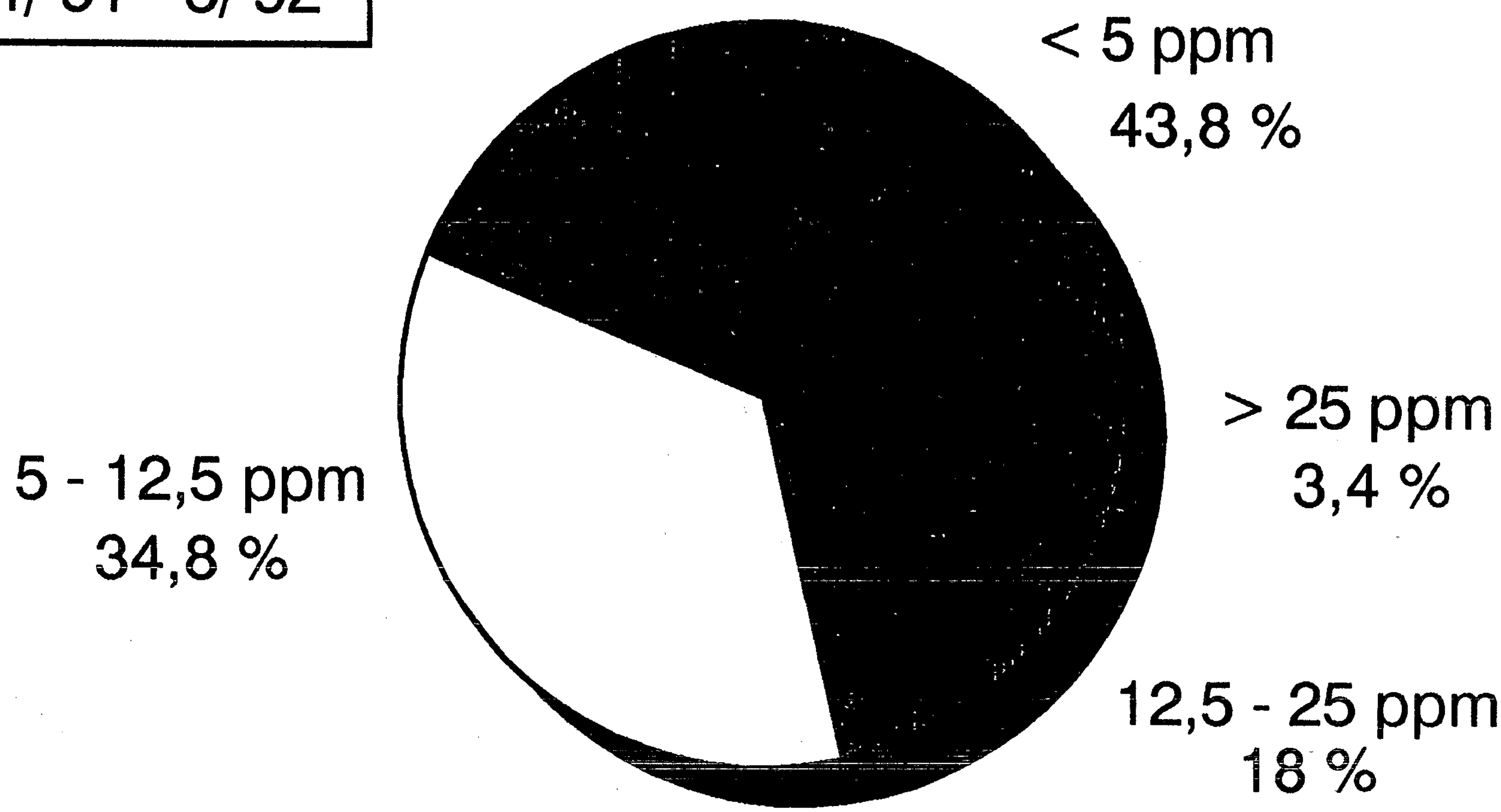
- the employees need not to be regularly examined by a doctor,
- otherwise the drycleaner has to pay for the examination of the employees.

(EPA20 Pi)

4

Perchloroethylen in Working Rooms

4/'91 - 5/'92

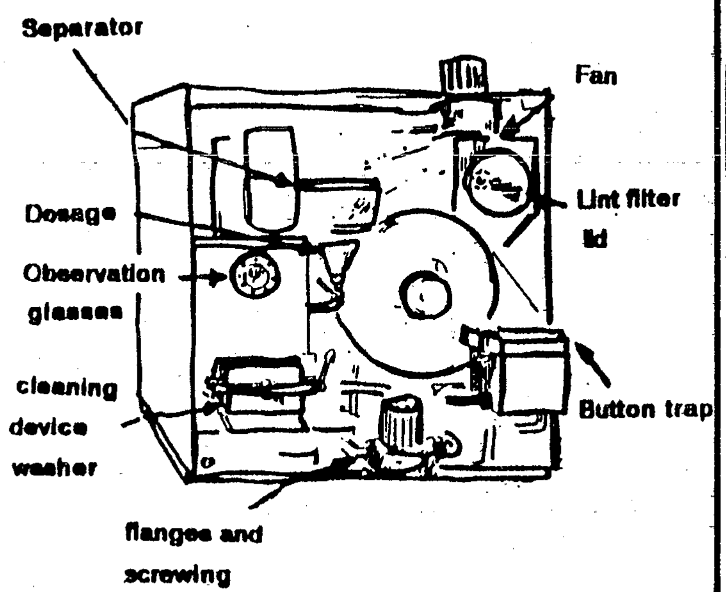


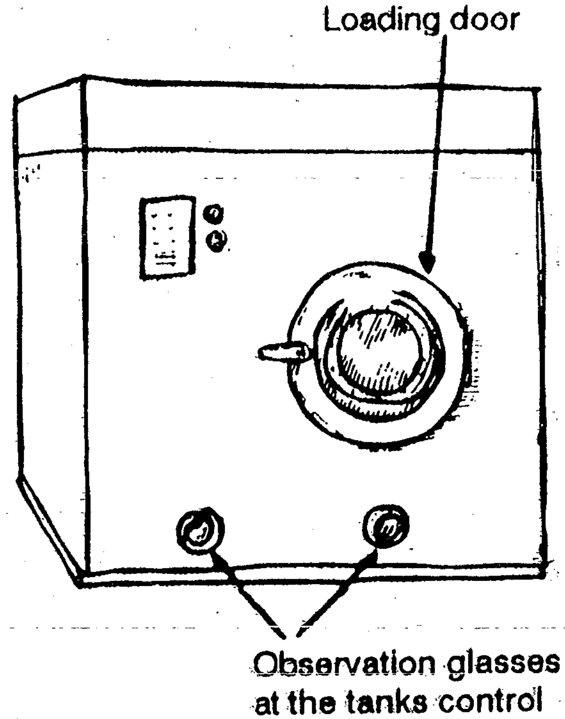
(I PA31 P)

EPA Roundtable	**Prevention of Emissions**	Institute Hohenstein

5.1 *Machine (s) - Leakage Check*

Electronic PCE - Detector (.200 $), Check frequency: **Daily**





(EPA16Pi)

5.2 *Machine (s) - Recording of Leakage Check*

The result must be recorded; if leakages are found, day and type of maintenance must be recorded

Leakage Check

Day:

Cleaning System	Result
o Loading door o Lint Filter o ______ o ______	______ ______ ______ ______
Still	**Result**
o ______ o ______ o ______ o ______	______ ______ ______ ______

Maintenance

Day	Type of Work

(EPA19 Pi)

5.3 *Handling*

Filling with solvent

Gas-exchange between barrel/container and tank/cage to be filled.

Cleaning the button trap

Solvent containing lints must be put in a closed container.

Aim: Dyring the lints inside of the button cage during drying.

Spotting without solvent containing mixtures

- -Perchloroethylen can no longer be used for prespotting.
- - 1,1,1-Tric is prohibites for post-spotting

Dosing of detergents/sizings/water-repellent agents etc.

Dosage automatically; when manually operated the valve must close self-acting.

Removing the residues from the still

Residues must not be removed when hot.

Removal under avoiding emission by
-semi-closed
-closed removal systems

Generally: Use of solvent only in the machine

No spraying of suede and leather with solvent-containing oil/fat.

No manually cleaning of upholstered furniture with perchloroethylene.

(EPA29 Pi)

27. / 28.05.1992

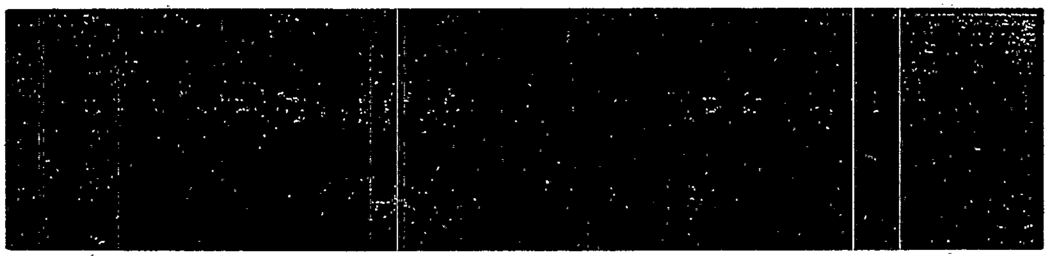
Prepared for Discussion

Measuring Devices and Test Results

EPA73 KU

EPA Roundtable	**Josef Kurz**	Institute Hohenstein

Survey



1.1. Necessity
1.2. Necessity
2. Activating the Industry
3. Test and Research Programs
4. Test Arrangement
5. Task
6. Composition of the Drycleaning Air in Drycleaning Machines
7.1. Components in the Drying Air
7.2. List of Components in the Drying Air
7.3. Important Components in Drying Air
8. Valve Control
9. Evaluation
10. Tested Measuring Devices

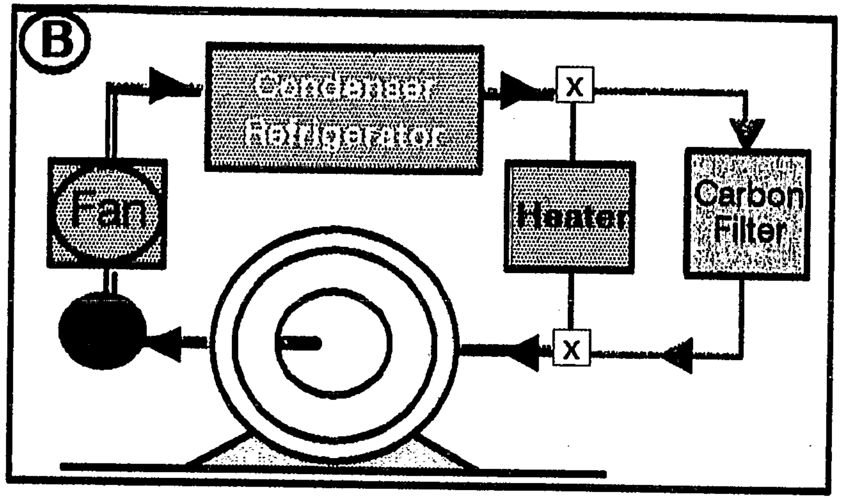
EPA74KU

D

I. Closed circuit machine with integrated carbon filter

Measuring point:
Air outlet of the cage

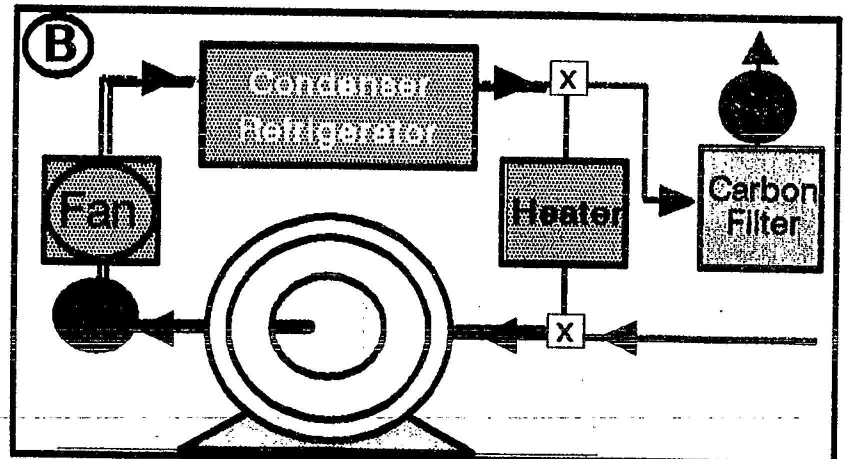
Threshold value:
2 g Perchloroethylene /m^3



II. Exhausting machine with activated carbon filter in the outlet air

Measuring point:
Air outlet of the cage <u>and</u> after activated carbon filter

Threshold value:
Air outlet of cage: 2 g / m^3
After carbon filter: 20 mg / m^3



EPA 40 KU

III. Work room

- Continuously measurement
- Occupational exposure limit: 50 ppm (345 mg / m^3),

  Measuring equipment is compulsory.

- Discontinuous measurement

  12,5 ppm (3 measurements within 3 month)

  5 ppm (1 measurement a year)

EPA 41 KU

EPA Roundtable	Measurement Equipment	Institute Hohenstein

1. **Invention Impulses**

   1989: Two years before the new regulation for dycleaning machines came into force, the Umweltbundesamt Berlin (UBA) asked Institute Hohenstein to inform all manufacturers of measuring equipment about the prospective obligation for measurement of perchloroethylene concentration in drycleaning machines.

2. At this time, there was no appropriate equipment available on the German market, despite of high - priced apparatures from 20 000 $ - 40 000 $ and rather complicated to operate.

3. When the information was introduced to the industry, an initiation was given for research and development.

EPA 55 KU

EPA Roundtable	**Measurement Equipment**	Institute Hohenstein

1. Umweltbundesamt asked Institute Hohenstein to start a program in order to test the available and offered equipment on their adaptability to drycleaning machines.
   The test was financed by UBA and the drycleaning industry.
   It was started with 8 measurement devices. Results of the tests are given on the following charts.

2. Ministry of Research and Technology (BMFT) supported a reseach program between 4 partners:

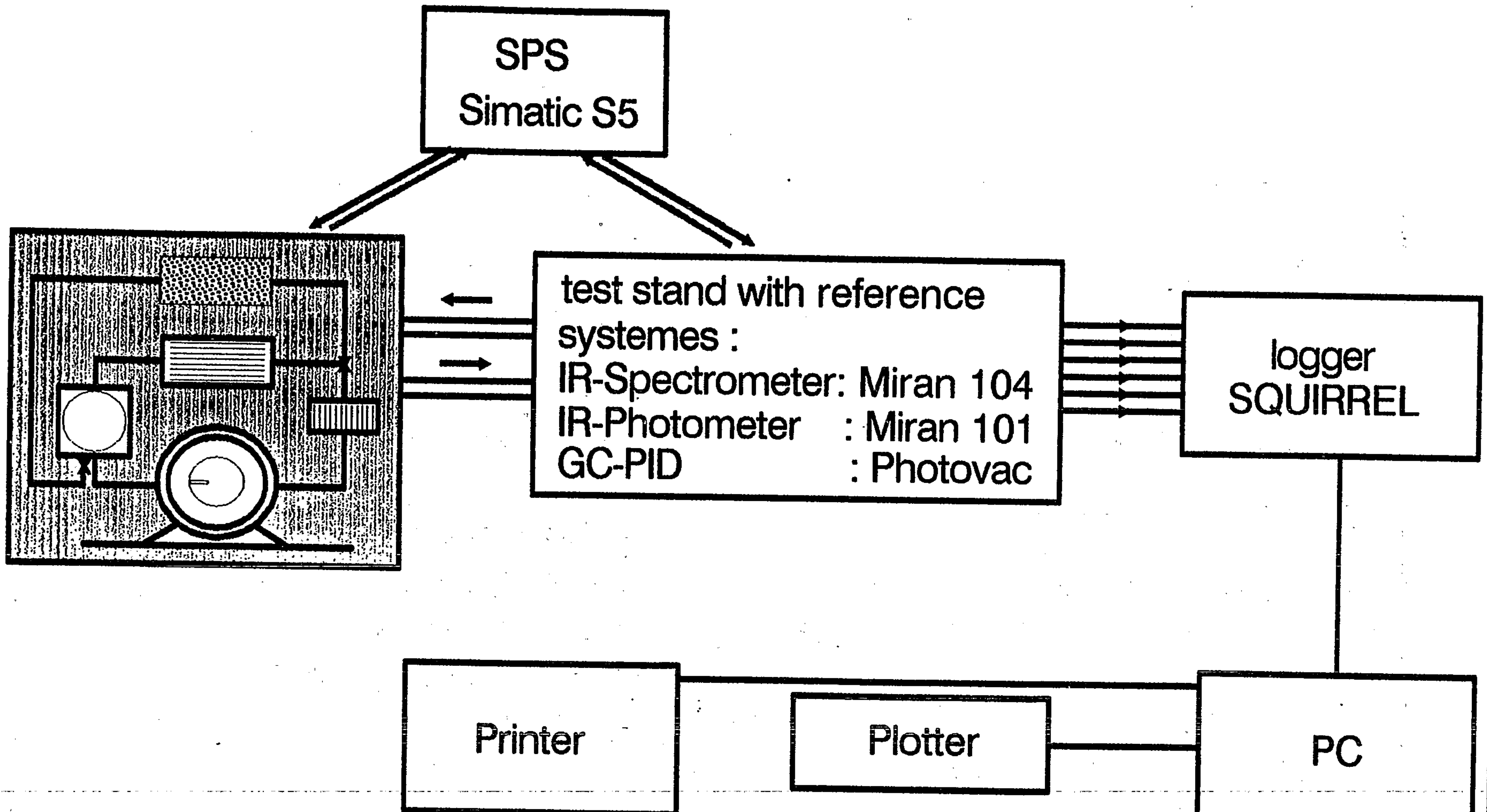
   - Frauenhofer Gesellschaft Freiburg
   - Institute Hohenstein
   - University of Tübingen
   - University of Freiburg

   The volume of the subsidy is 5 Million $, the duration is 3 years, beginning in 1989, ending 1992.
   The aim of the research program is to develop new sensitive films for cheap sensors in drycleaning machines and other technical applications.

EPA 56 KU

4

Test Arrangement



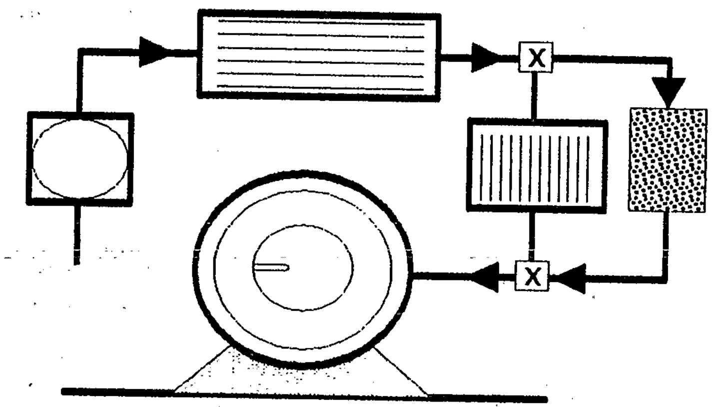
(EPA2 Pi)

5

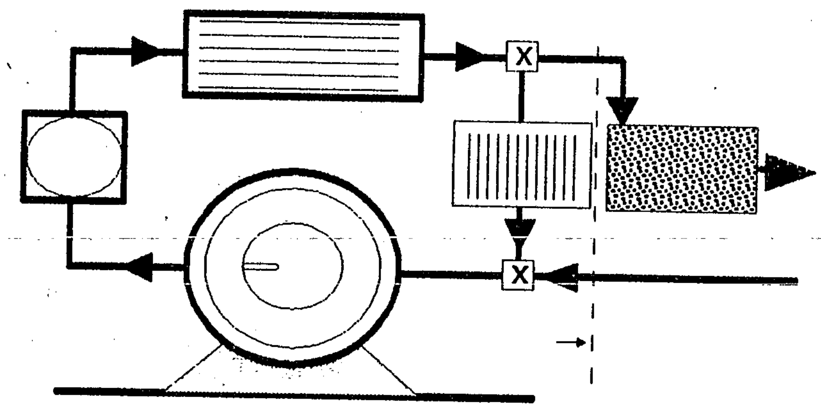
Task

Measurement of Perchlorethylen Concentration in:

the outlet air of closed circuit machines with integrated carbon filters
2 g/m^3



the outlet air of exhausting machines with carbon filters - 1 g/m^3 as an indication for the threshold value of 20 mg/m^3



(EPA15 Pi)

6 *Composition of the Drying Air in Drycleaning Machines*

Fundamental:

Drying air contents oxygen, nitrogen, gaseous water, perchloroethylene and different amounts of solvents out of the drycleaning aids (detergents, pre- and postspotting agents, water repellents, etc.)

Tests:

Measurement of the concentrations of perchloroethylene

Question:

Which gaseous components in the drying air disturb the measurement of perchloroethylene?

Answer:

Research results on following charts

(EPA10 Pi)

7.1. *Components in the Drying Air*

Oxygen and nitrogen are not regarded

Qualitative Analysis

Almost all drycleaning aids on the german market were tested.

See chart 7.2.

List of Components in Drying Air

Quantitative Analysis

Only of components with more than 0,01% of the volume were regarded.

See chart 7.3.

Important Components in Drying Air

All measurements were made with gaschromatography and IR - spectroscopy (EPA11 Pi)

7.2. *List of Components in Drying Air*

Chlorine Free Solvents

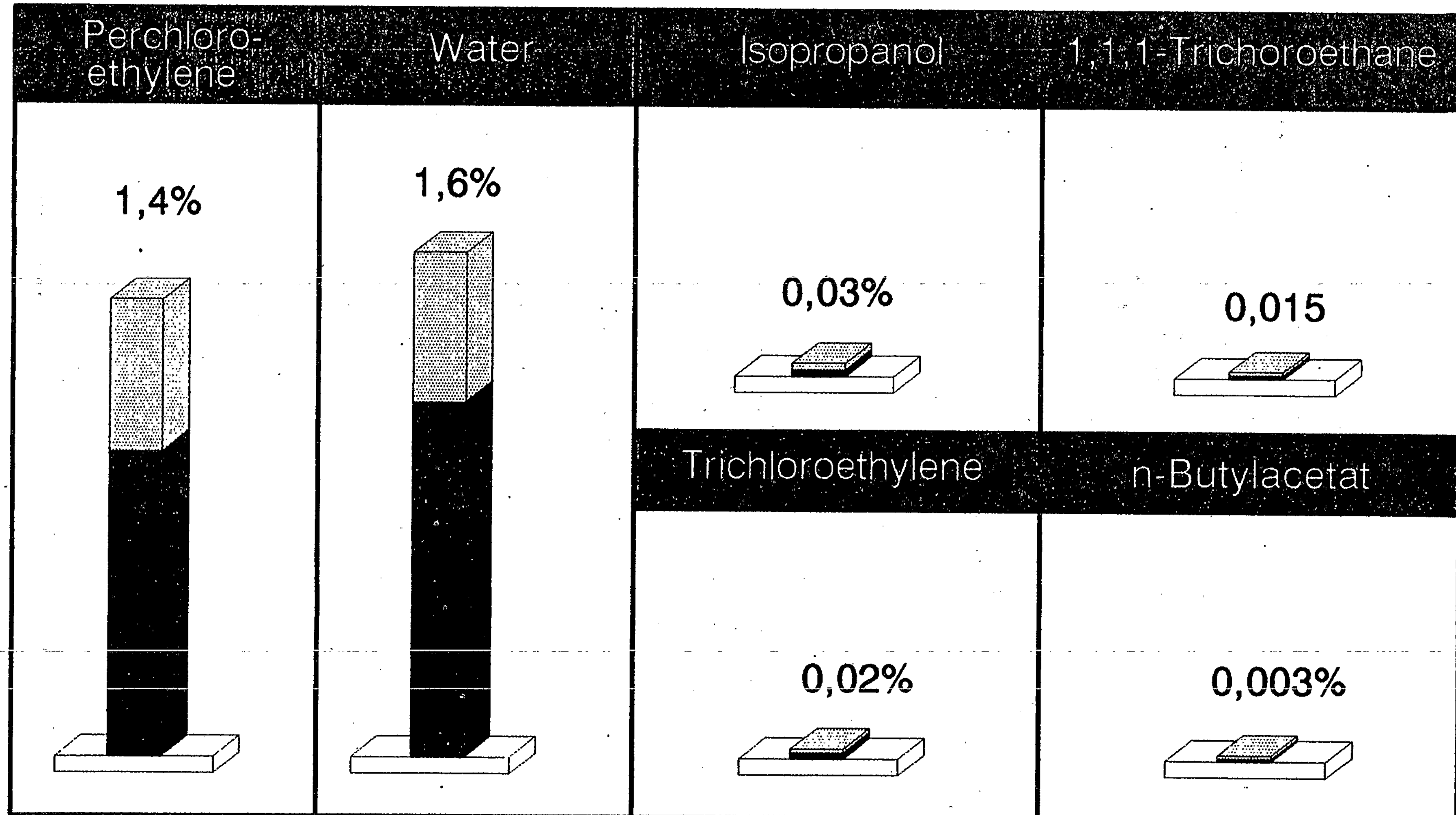
Ethanol	n - Butylacetat
n - Propanol	2 - Butylacetat
2 - Propanol	Amylacetat
Amylalkohol	Butyldiglycolacetate
Cyclohexanol	Hydrocarbons: n - Aliphatic compounds iso - aliphatic compounds Cycloaliphatic compounds with 8 to 10 C-atoms
Diethyleneglycol	Aromatic hydrocarbons
Butyldiglycol	Gaseous Water
Acetone	
Ethylmethylketone	
Ethylacetat	

Chlorinated Solvents

Dichloromethane	1,1,1-Trichloroethane
Chloroform	1,1,2,2-Tetrachloroethane
Tetrachloromethane	Trichloroethylene
Dichloroethane	1,1,2-Trichlorotrifluoroethane

(EPA3 Pi)

7.3. *Important components in Drying Air (% Vol.)*



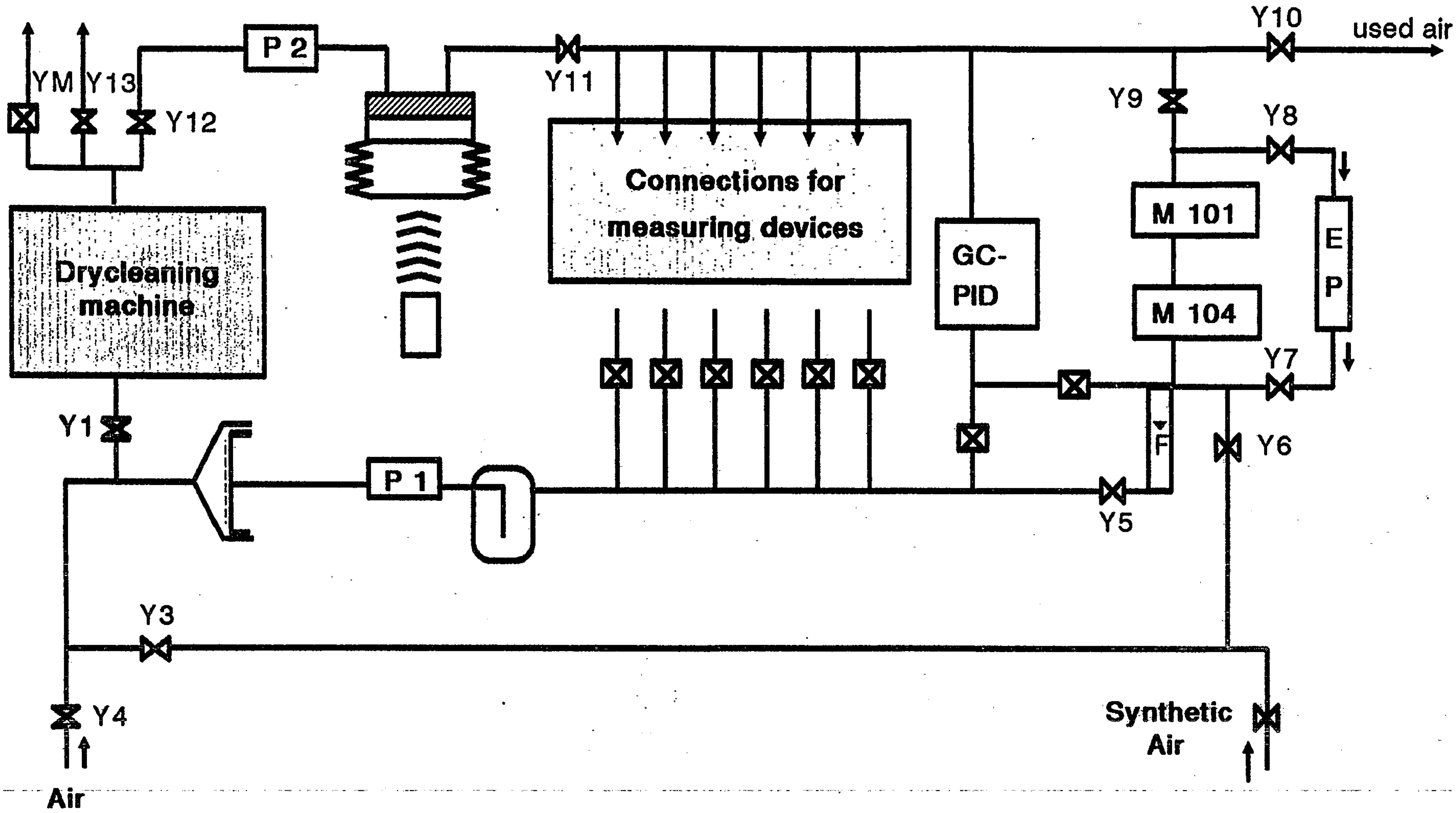
(EPA13Pi)

EPA Roundtable

Institute Hohenstein

8

Valve Control

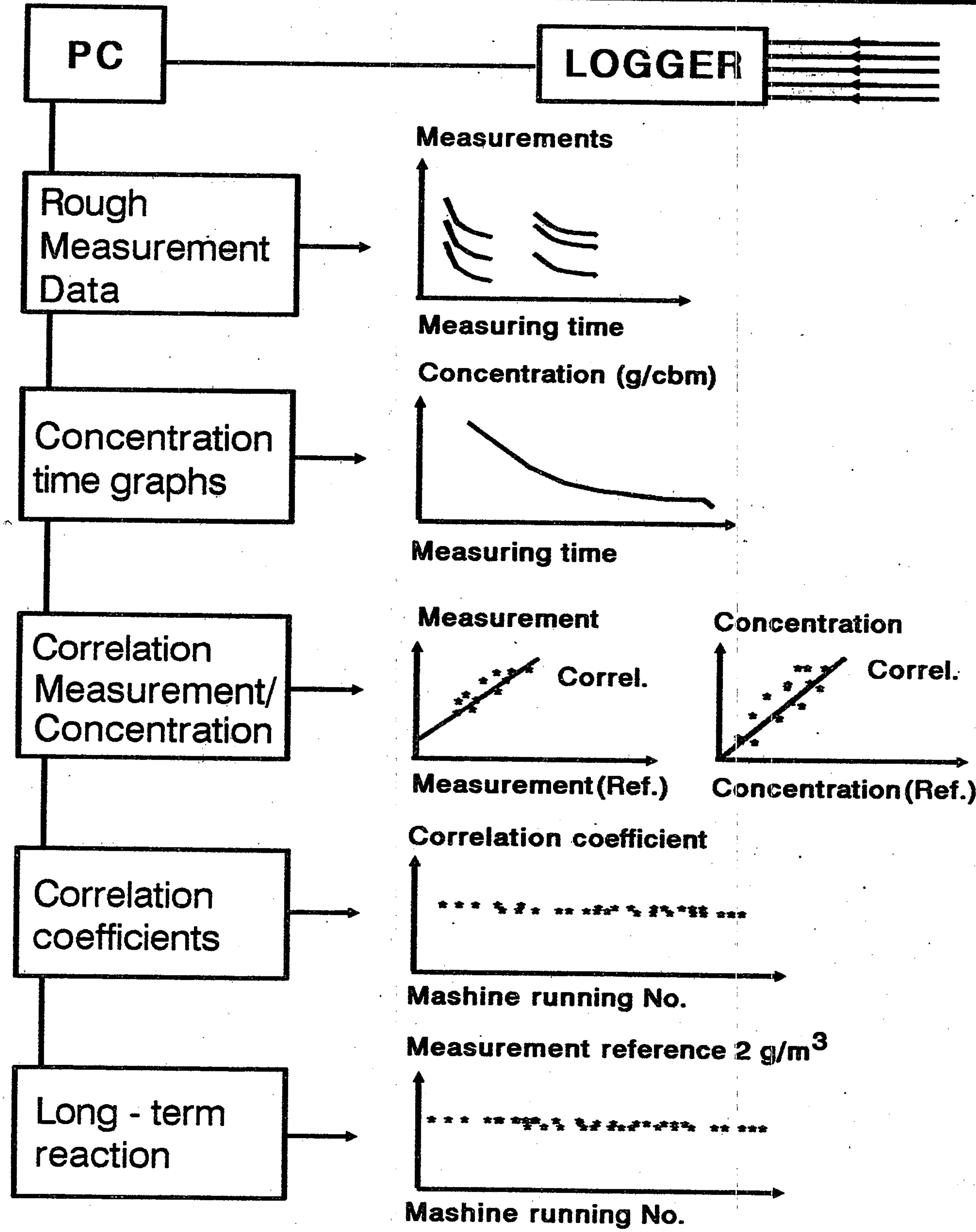


(EPA4 Pi)

EPA Roundtable

Institute Hohenstein

9 Evaluation



(EPA6 Pi)

10

Tested Measuring Devices

MOS without any equipment

(A) IST / UPK

MOS with permeation tube

(B) MECCOS - EN

MOS with a GC column

(C) METATRON

Heat conductivity detector

(D) Consens 1P + adsorber

Photoionisation Detectors

(E) SIP 1000; 10,6 EV

(F) Solvektor; 10,2 EV

INFRARED - Systems

(G) UNOR 6N; Reference CFC 12

(H) M.A.C. 2022; 12,8 or 10,9 µm

(I) P.M.S. 2000; 10,9 µm

REFERENCE + MEASUREMENT

(K) MIRAN 104; 11,1 µm

(L) MIRAN 101; 12,8 µm

(M) Gaschromatograph, Photovac PID; 10,6 EV

(EPA5 Pi)

27. / 28.05.1992

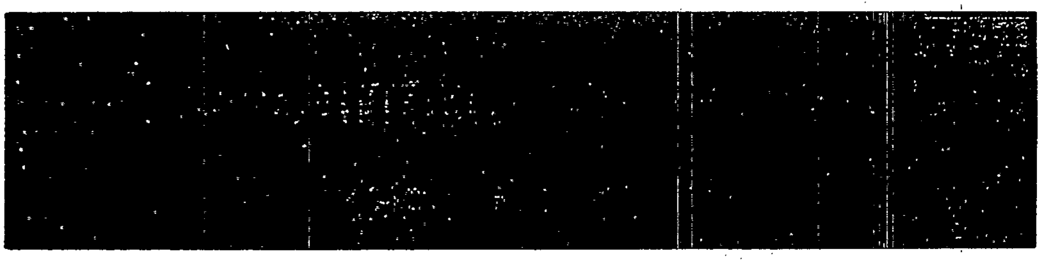
Prepared for Discusssion

Measuring Devices and Test Results

EPA73 KU

EPA Roundtable	Josef Kurz	Institute Hohenstein

Survey



- 1.1. Necessity
- 1.2. Necessity
- 2. Activating the Industry
- 3. Test and Research Programs
- 4. Test Arrangement
- 5. Task
- 6. Composition of the Drycleaning Air in Drycleaning Machines
- 7.1. Components in the Drying Air
- 7.2. List of Components in the Drying Air
- 7.3. Important Components in Drying Air
- 8. Valve Control
- 9. Evaluation
- 10. Tested Measuring Devices

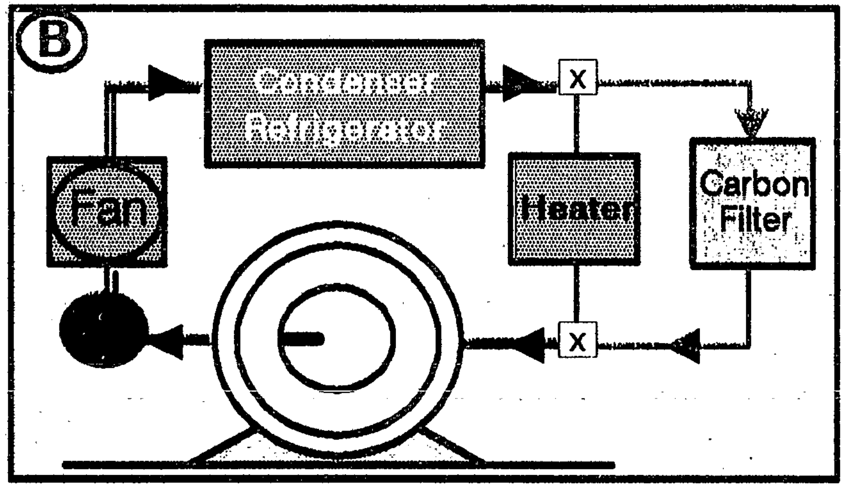
EPA74KU

D

I. Closed circuit machine with integrated carbon filter

Measuring point:
Air outlet of the cage

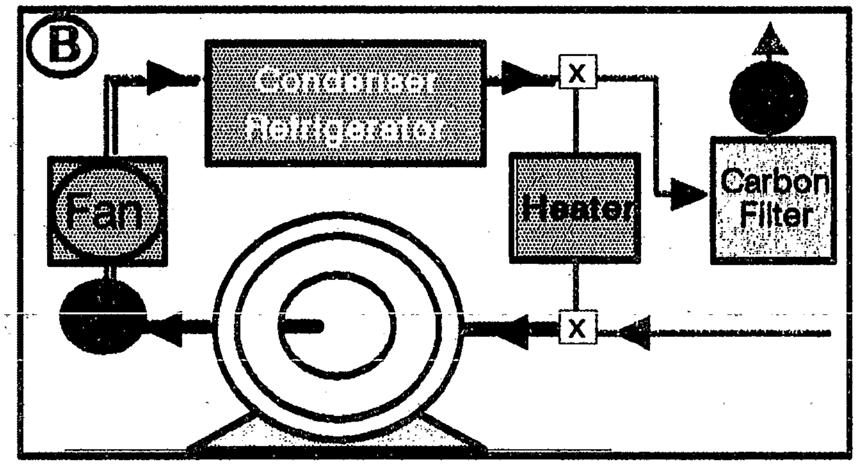
Threshold value:
2 g Perchloroethylene /m^3



II. Exhausting machine with activated carbon filter in the outlet air

Measuring point:
Air outlet of the cage <u>and</u>
after activated carbon filter

Threshold value:
Air outlet of cage: 2 g / m^3
After carbon filter: 20 mg / m^3



EPA 40 KU

III. Work room

- Continuously measurement
- Occupational exposure limit: 50 ppm (345 mg / m^3),

  Measuring equipment is compulsory.

- Discontinuous measurement

  12,5 ppm (3 measurements within 3 month)

  5 ppm (1 measurement a year)

EPA-41 KU

1. **Invention Impulses**

   1989: Two years before the new regulation for dycleaning machines came into force, the Umweltbundesamt Berlin (UBA) asked Institute Hohenstein to inform all manufacturers of measuring equipment about the prospective obligation for measurement of perchloroethylene concentration in drycleaning machines.

2. At this time, there was no appropriate equipment available on the German market, despite of high - priced apparatures from 20 000 $ - 40 000 $ and rather complicated to operate.

3. When the information was introduced to the industry, an initiation was given for research and development.

EPA 55 KU

EPA Roundtable	**Measurement Equipment**	Institute Hohenstein

1. Umweltbundesamt asked Institute Hohenstein to start a program in order to test the available and offered equipment on their adaptability to drycleaning machines.
The test was financed by UBA and the drycleaning industry.
It was started with 8 measurement devices. Results of the tests are given on the following charts.

2. Ministry of Research and Technology (BMFT) supported a reseach program between 4 partners:

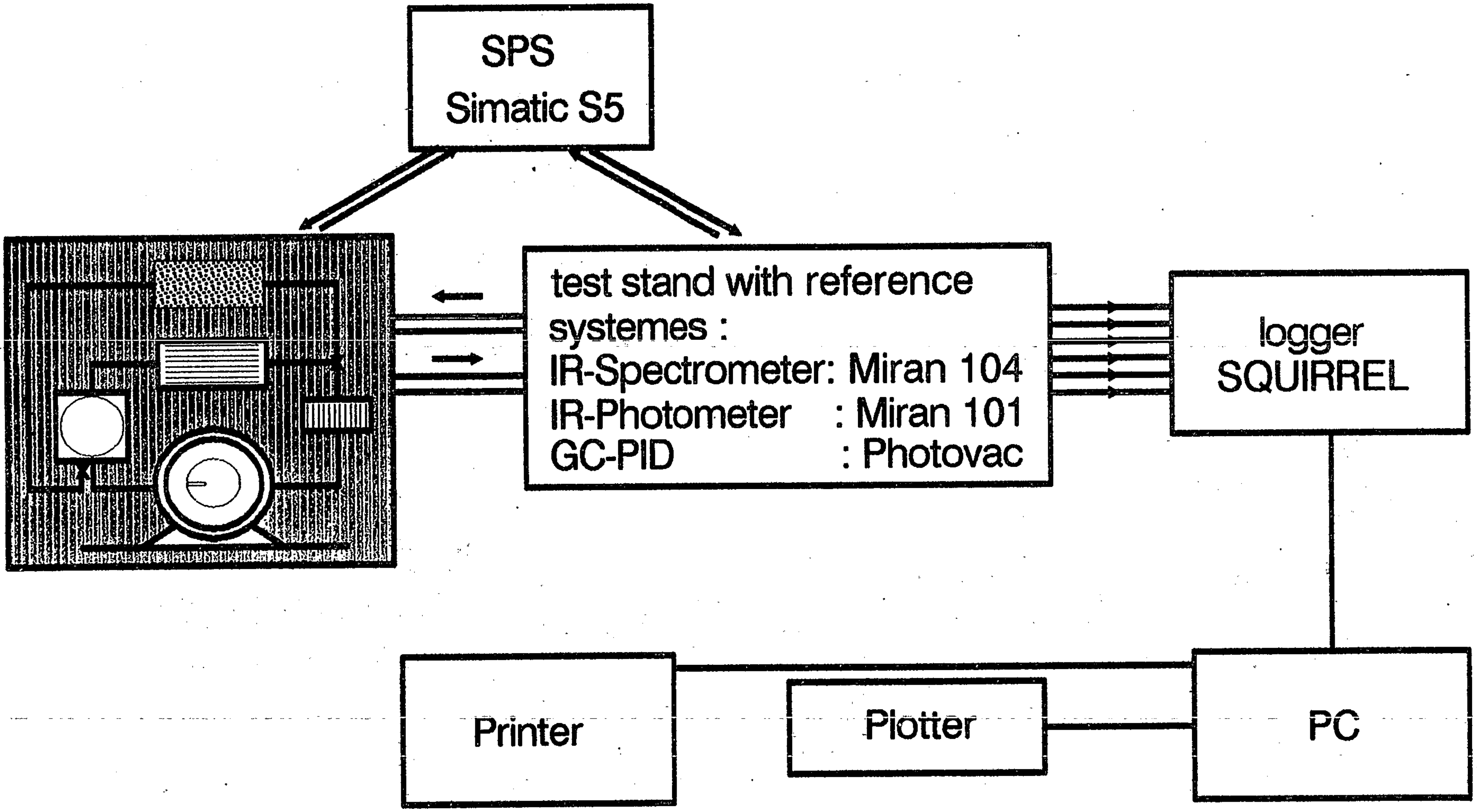
- Frauenhofer Gesellschaft Freiburg
- Institute Hohenstein
- University of Tübingen
- University of Freiburg

The volume of the subsidy is 5 Million $, the duration is 3 years, beginning in 1989, ending 1992.
The aim of the research program is to develop new sensitive films for cheap sensors in drycleaning machines and other technical applications.

EPA 56 KU

4

Test Arrangement



(EPA2 Pi)

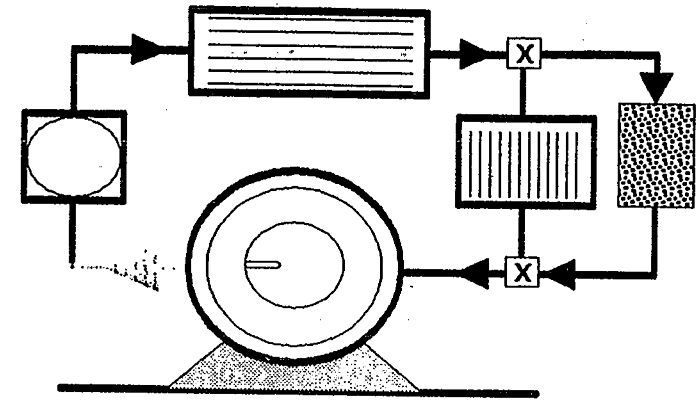
5

Task

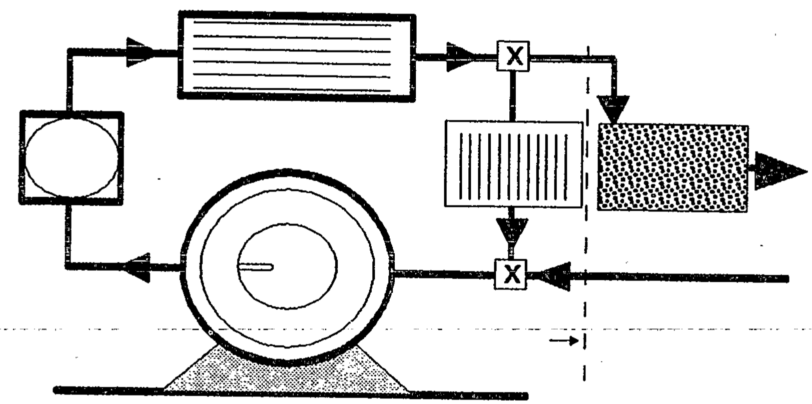
Measurement of Perchlorethylen Concentration in:

the outlet air of closed circuit machines with integrated carbon filters

2 g/m³



the outlet air of exhausting machines with carbon filters, only as an indication in the threshold value of [illegible] mg/m³



(EPA15 Pi)

6

Composition of the Drying Air in Drycleaning Machines

Fundamental:

Drying air contents oxygen, nitrogen, gaseous water, perchloroethylene and different amounts of solvents out of the drycleaning aids (detergents, pre- and postspotting agents, water repellents, etc.)

Tests:

Measurement of the concentrations of perchloroethylene

Question:

Which gaseous components in the drying air disturb the measurement of perchloroethylene?

Answer:

Research results on following charts

(EPA10Pi)

EPA Roundtable | Institute Hohenstein

7.1. *Components in the Drying Air*

Oxygen and nitrogen are not regarded

Qualitative Analysis

Almost all drycleaning aids on the german market were tested.

See chart 7.2.

List of Components in Drying Air

Quantitative Analysis

Only of components with more than 0,01% of the volume were regarded.

See chart 7.3.

Important Components in Drying Air

All measurements were made with gaschromatography and IR - spectroscopy (EPA11 Pi)

EPA Roundtable **Institute Hohenstein**

7.2. *List of Components in Drying Air*

Chlorine Free Solvents

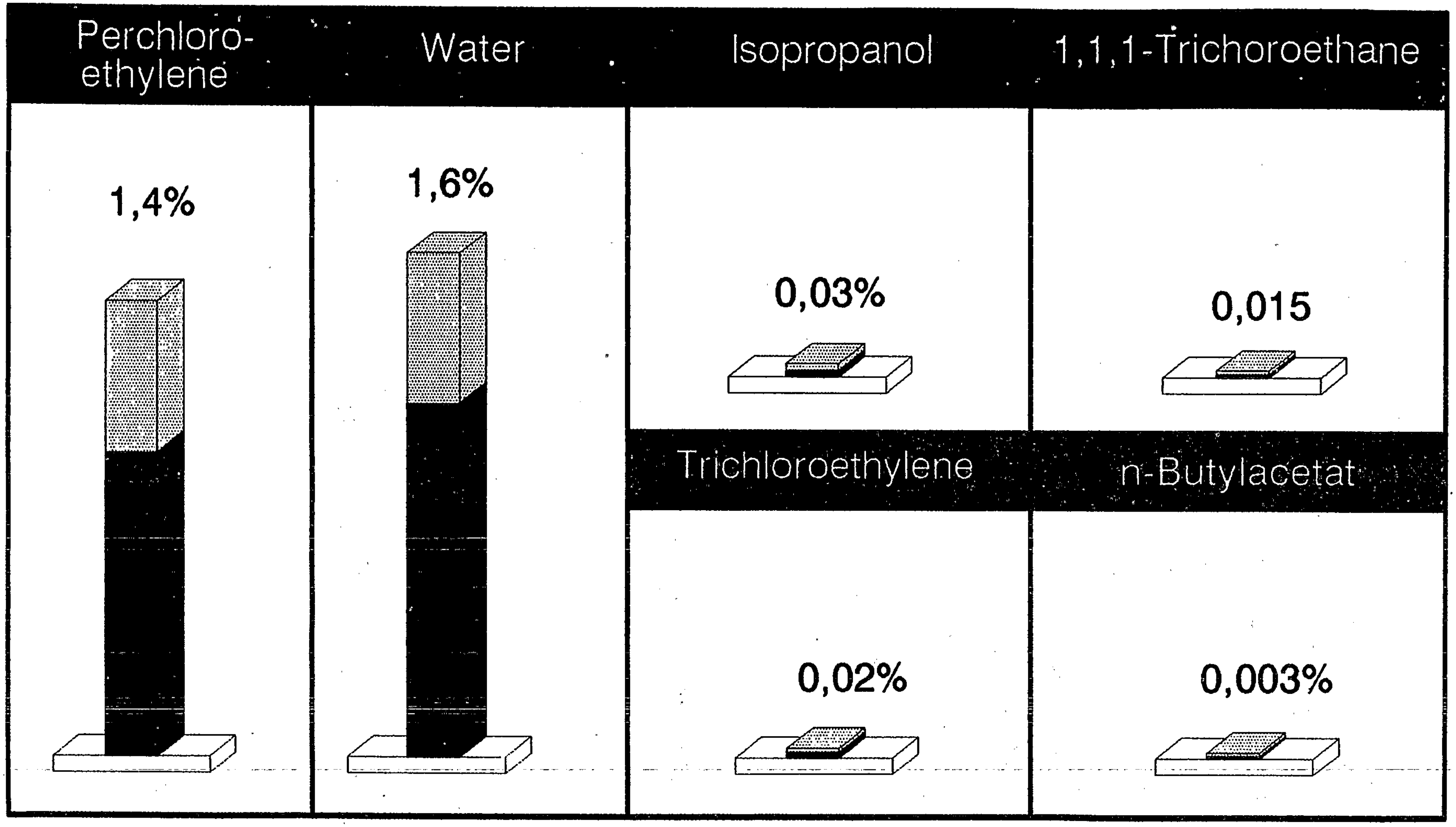
Ethanol	n - Butylacetat
n - Propanol	2 - Butylacetat
2 - Propanol	Amylacetat
Amylalkohol	Butyldiglycolacetate
Cyclohexanol	Hydrocarbons: n - Aliphatic compounds iso - aliphatic compounds Cycloaliphatic compounds with 8 to 10 C-atoms
Diethyleneglycol	Aromatic hydrocarbons
Butyldiglycol	Gaseous Water
Acetone	
Ethylmethylketone	
Ethylacetat	

Chlorinated Solvents

Dichloromethane	1,1,1-Trichloroethane
Chloroform	1,1,2,2-Tetrachloroethane
Tetrachloromethane	Trichloroethylene
Dichloroethane	1,1,2-Trichlorotrifluoroethane

(EPA3 Pi)

7.3. *Important components in Drying Air (% Vol.)*



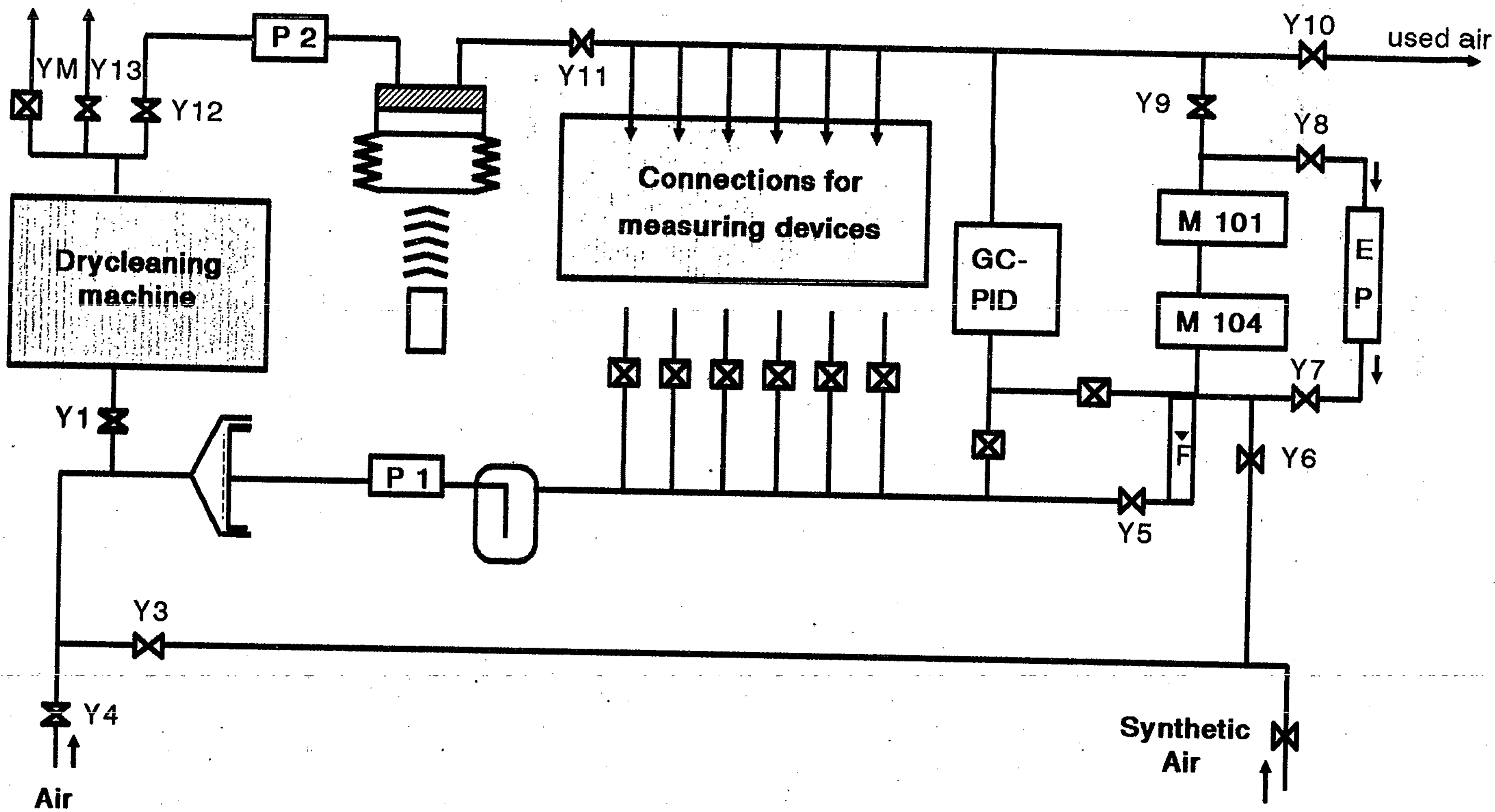
(EPA13 Pi)

EPA Roundtable

Institute Hohenstein

8

Valve Control

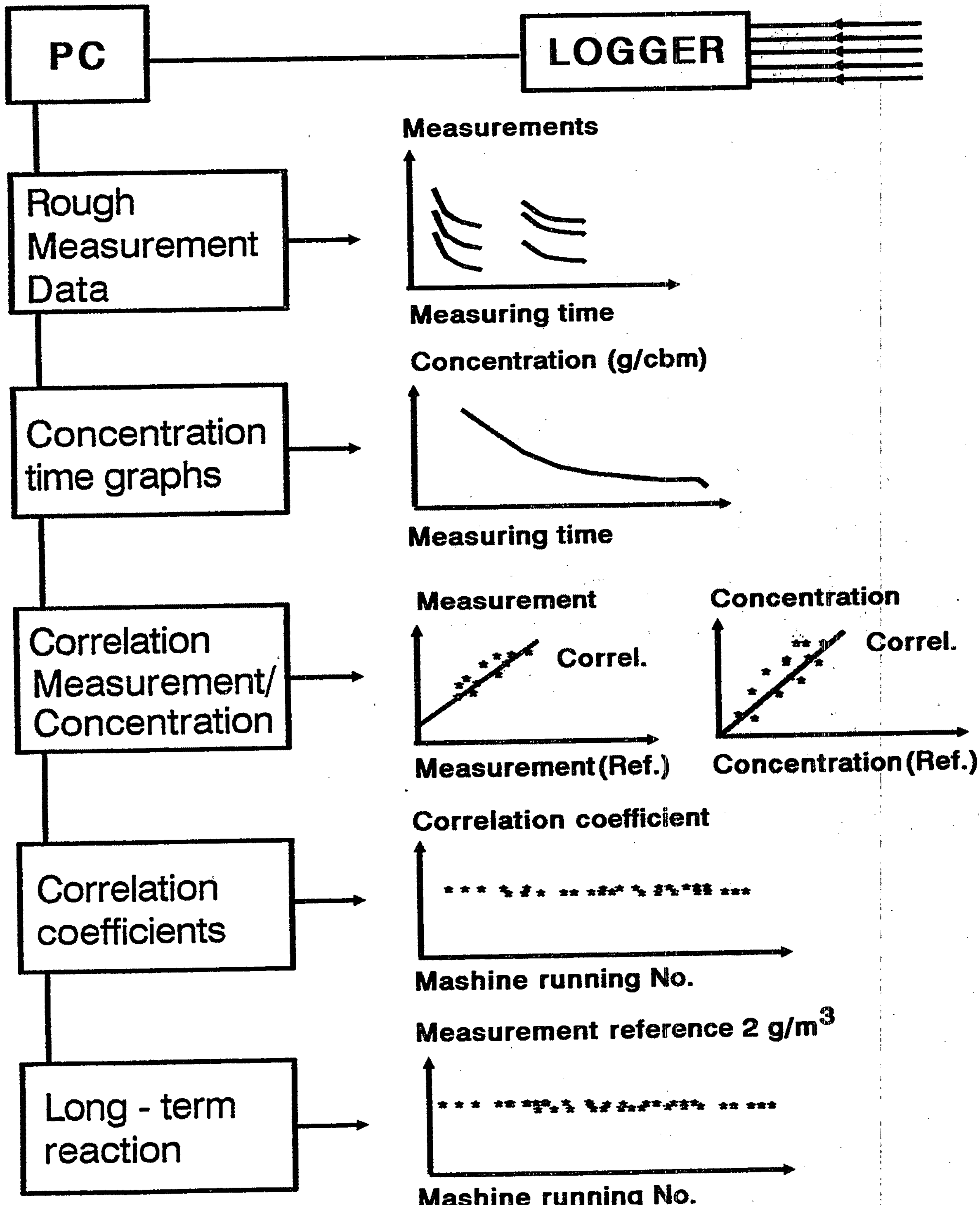


EPA Roundtable

(EPA4Pi)

Institute Hohenstein

9 *Evaluation*



(EPA6 Pi)

10

Tested Measuring Devices

MOS without any equipment

(A) IST / UPK

MOS with permeation tube

(B) MECCOS - EN

MOS with a GC column

(C) METATRON

Heat conductivity detector

(D) Consens 1P + adsorber

Photoionisation Detectors

(E) SIP 1000; 10,6 EV

(F) Solvektor; 10,2 EV

INFRARED - Systems

(G) UNOR 6N; Reference CFC 12

(H) M.A.C. 2022; 12,8 or 10,9 µm

(I) P.M.S. 2000; 10,9 µm

REFERENCE + MEASUREMENT

(K) MIRAN 104; 11,1 µm

(L) MIRAN 101; 12,8 µm

(M) Gaschromatograph, Photovac PID; 10,6 EV

(EPA5 Pi)

Prepared for Discussion

Residual Reduction

EPA26 KU

Survey

Residual Reduction

1. Residues in Textiles
2. Fundamental Facts
3. Deodorisation System

4.1. Perchloroethylene in Textiles

4.1.1.Machine Technology

4.2. Retention of Different Fibres/Textiles

5.1. Distribution of Perchloroethylene

5.2. Residues in Finished Textiles (Examples)

5.3. Retention of Fused Interlinings

5.4. Retention of Fused Interlinings (continued)

6. Finishing Treatments
7. Retention of Finish on Cotton

EPA25 KU

Residues in Textiles

Perchloroethylene

Research results of Institute Hohenstein obtained in the following research programs:

1. "Reduction of residual perchloroethylene in textiles", financed by the Ministry of Research and Technology (BMFT), coordinated by Deutsche Forschungsgesellschaft für Luft-und Raumfahrt (DLR).

   Coordinator: Dr.C.Verkoyen.

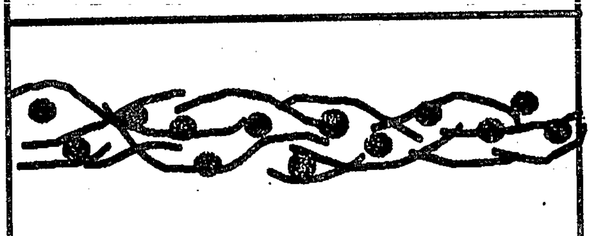
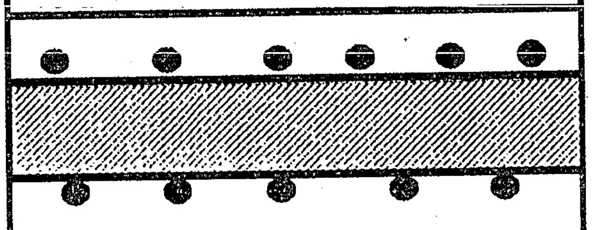
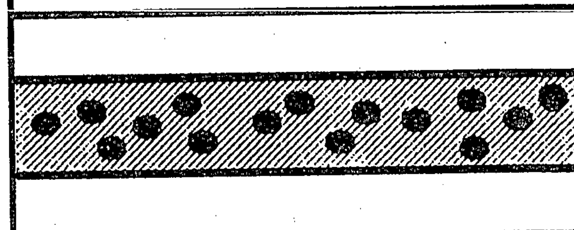
2. "Reduction of perchloroethylene emissions out of the drycleaning plants", financed by Umweltbundesamt (UBA) and Forschungsstelle Textilreinigung (FTR).

   Coordinator: Dr.H.Brackemann

EPA 27 KU

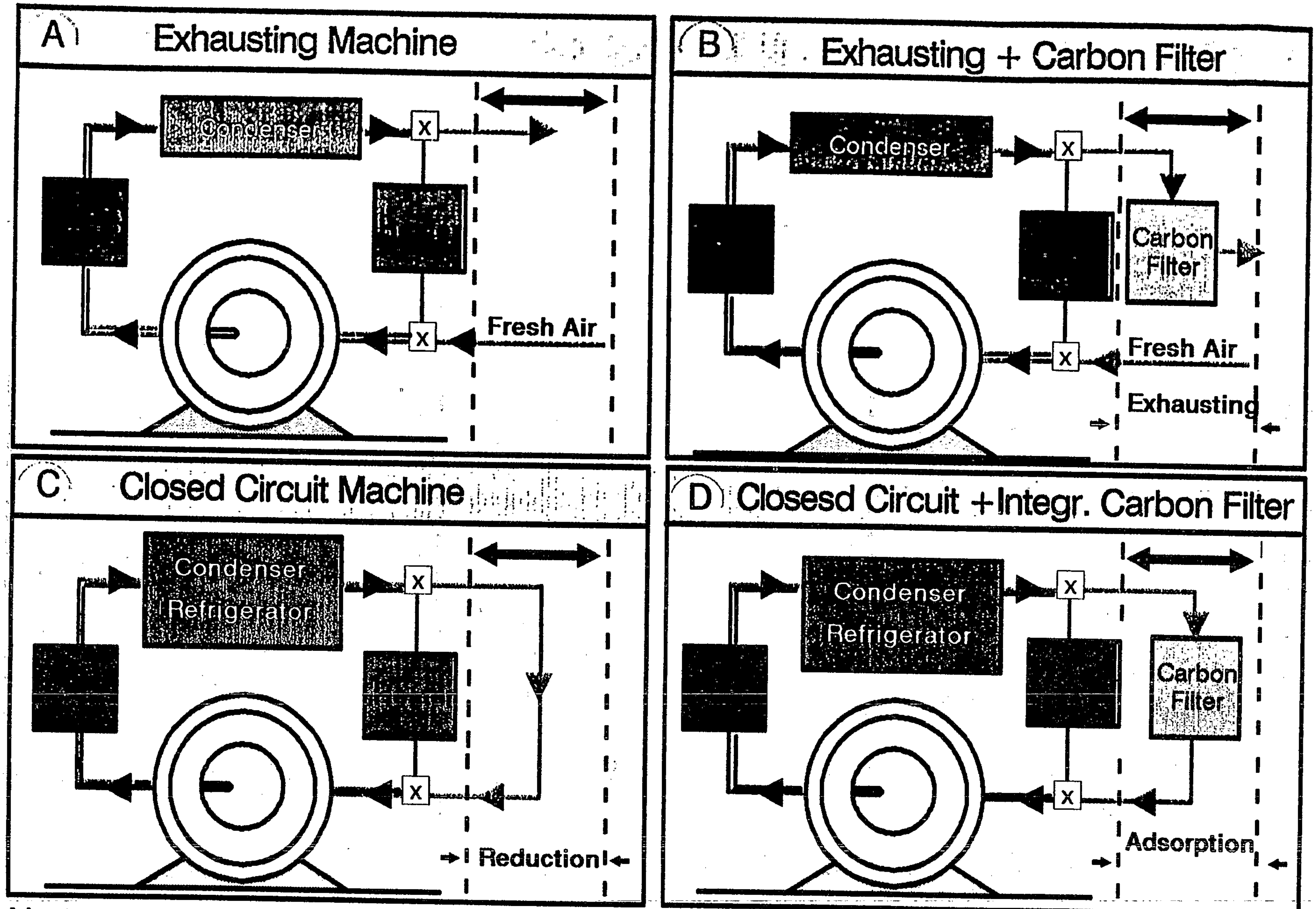
2 Fundamental Facts

Causes of Retention of Perchloroethylene by Textiles

Inclusion	Adsorption	Absorption
Gaseous perchloro-ethylene within the free space of fibres in yarns, knitwear, weavings, etc.	Gaseous perchloro-ethylene at the surface of fibres.	Solving at perchloro-ethylene in fibres (Polyester), resins, plastics, etc.
Removal: Intensive aeration	Removal: Intensive aeration	Removal: Diffusion / aeration
Mechanism	**Mechanism**	**Mechanism**
		

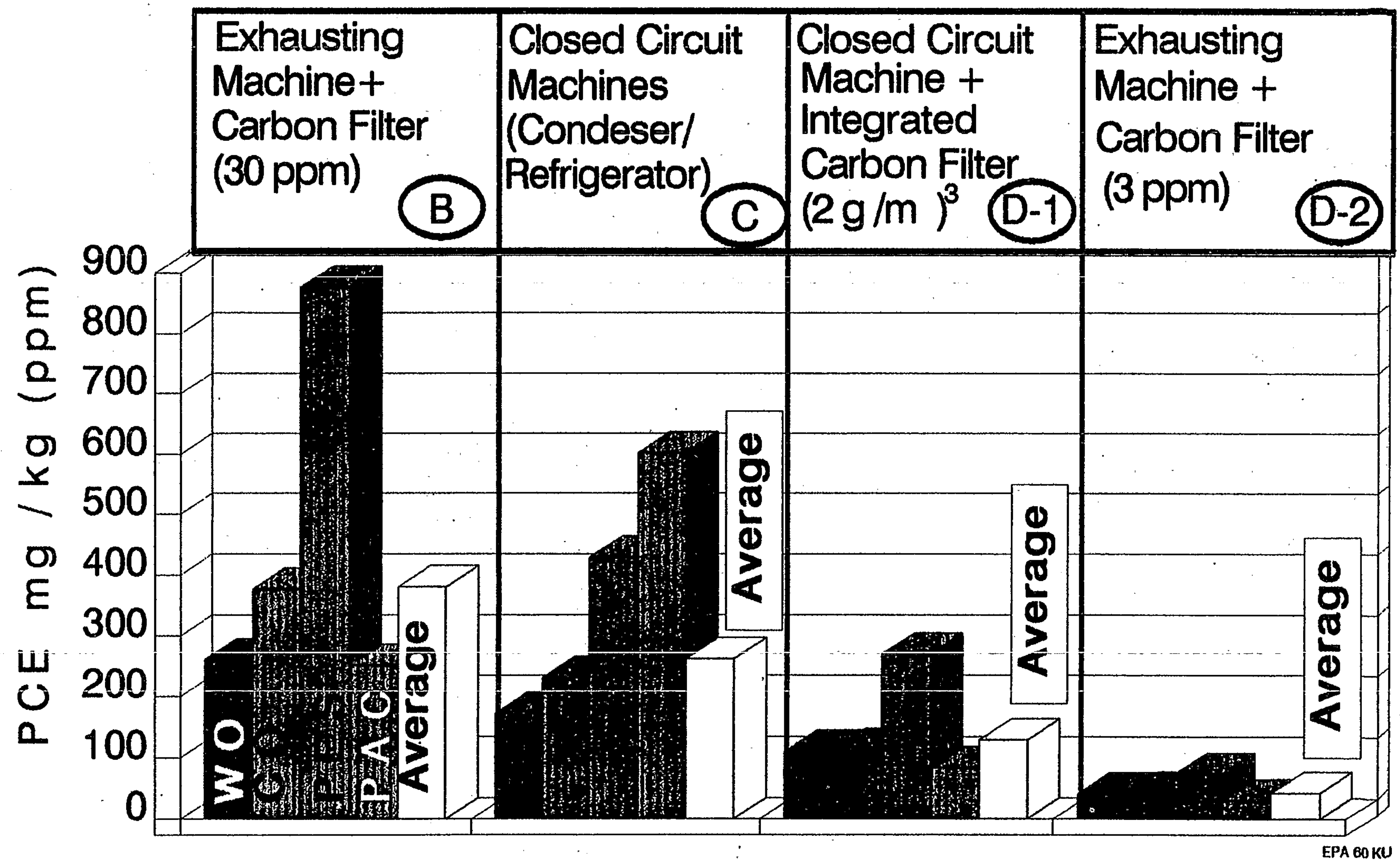
EPA 28 KU

EPA Roundtable	**Residual Reduction**	Institute Hohenstein



Nr. 3 Deodorisation System

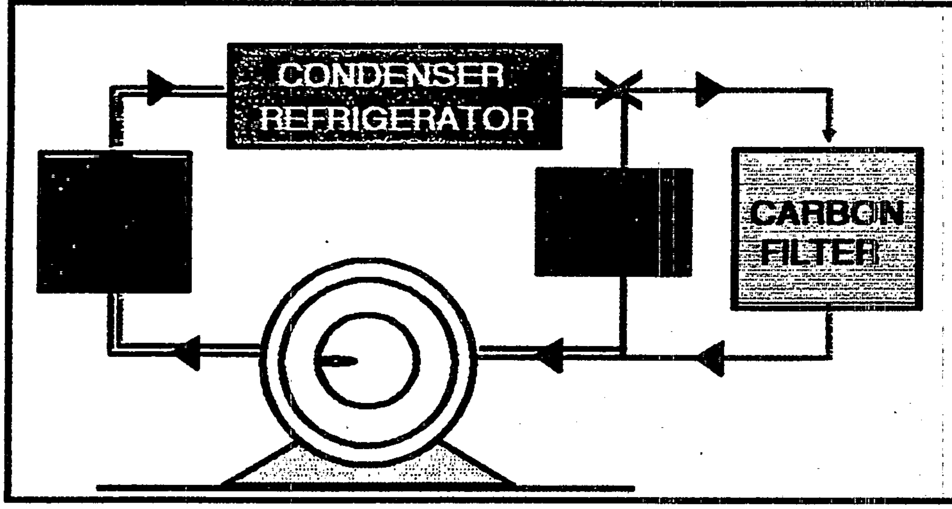
4.1 Perchloroethylene in Textiles



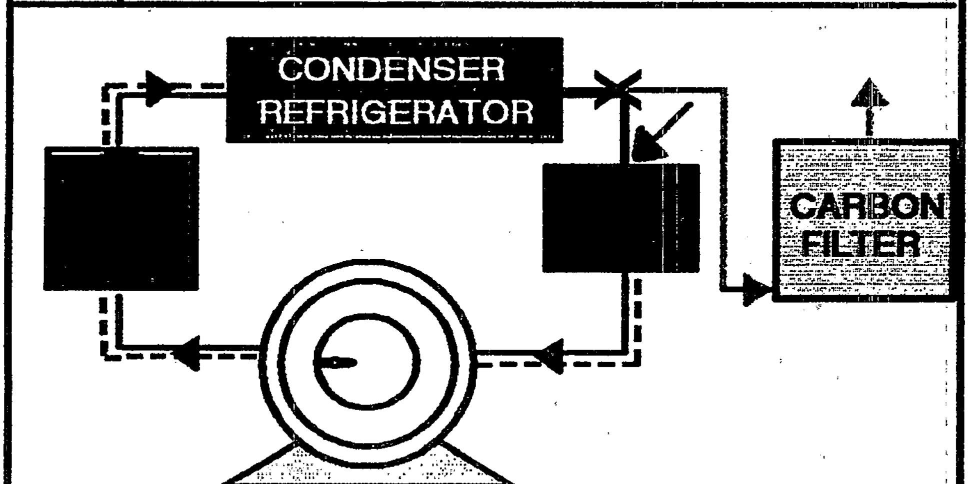
EPA Roundtable | **Residual Reduction** | Institute Hohenstein

4.1.1. Machine Technology

D-1 Closed Circuit Machine + Integrated Carbon Filter



D-2 Exhausting Machine + Integrated Carbon Filter

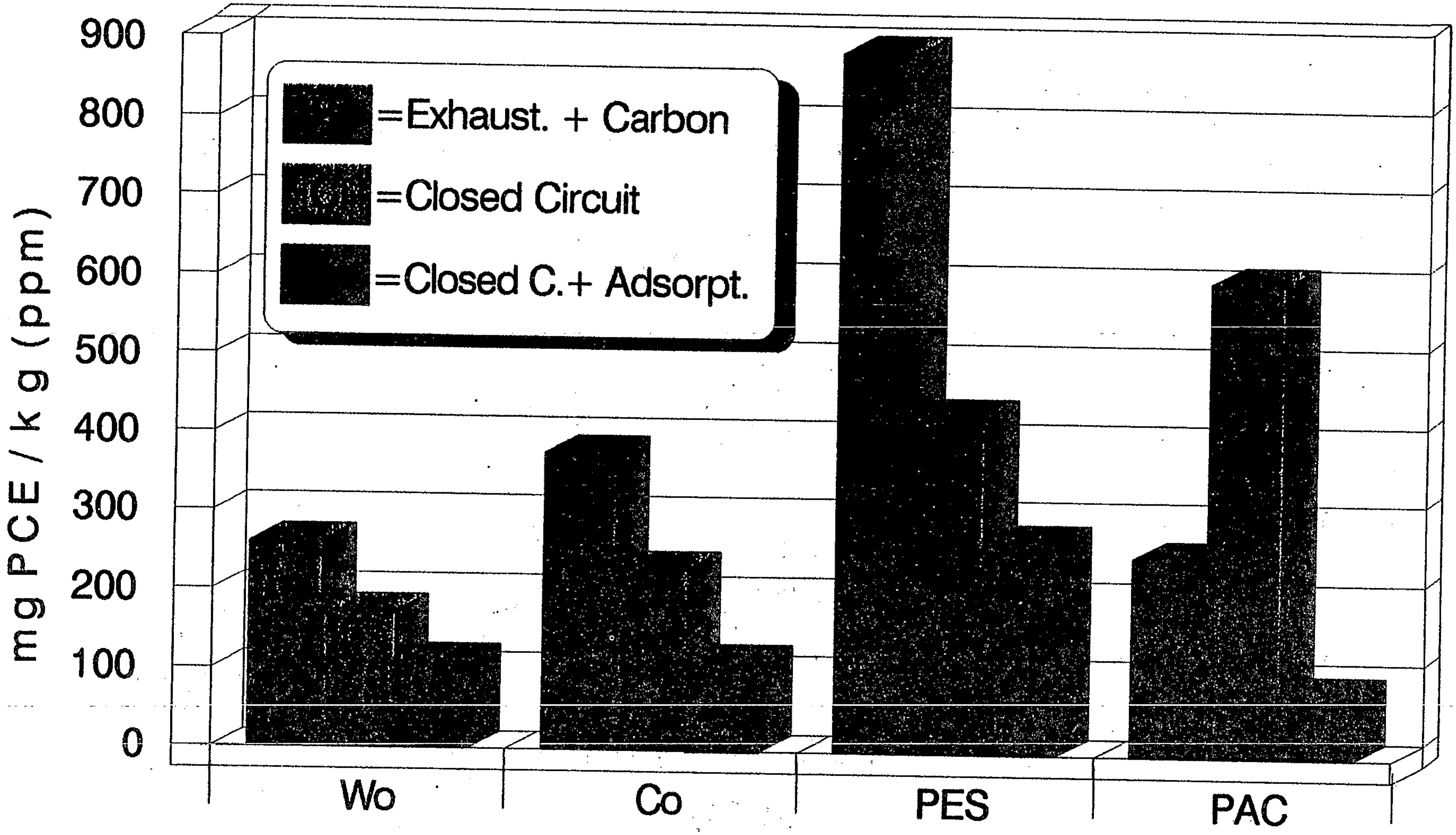


- - - - + ■ = Deodorisation Phase

■ = Drycleaning Cycle

EPA 18 KU

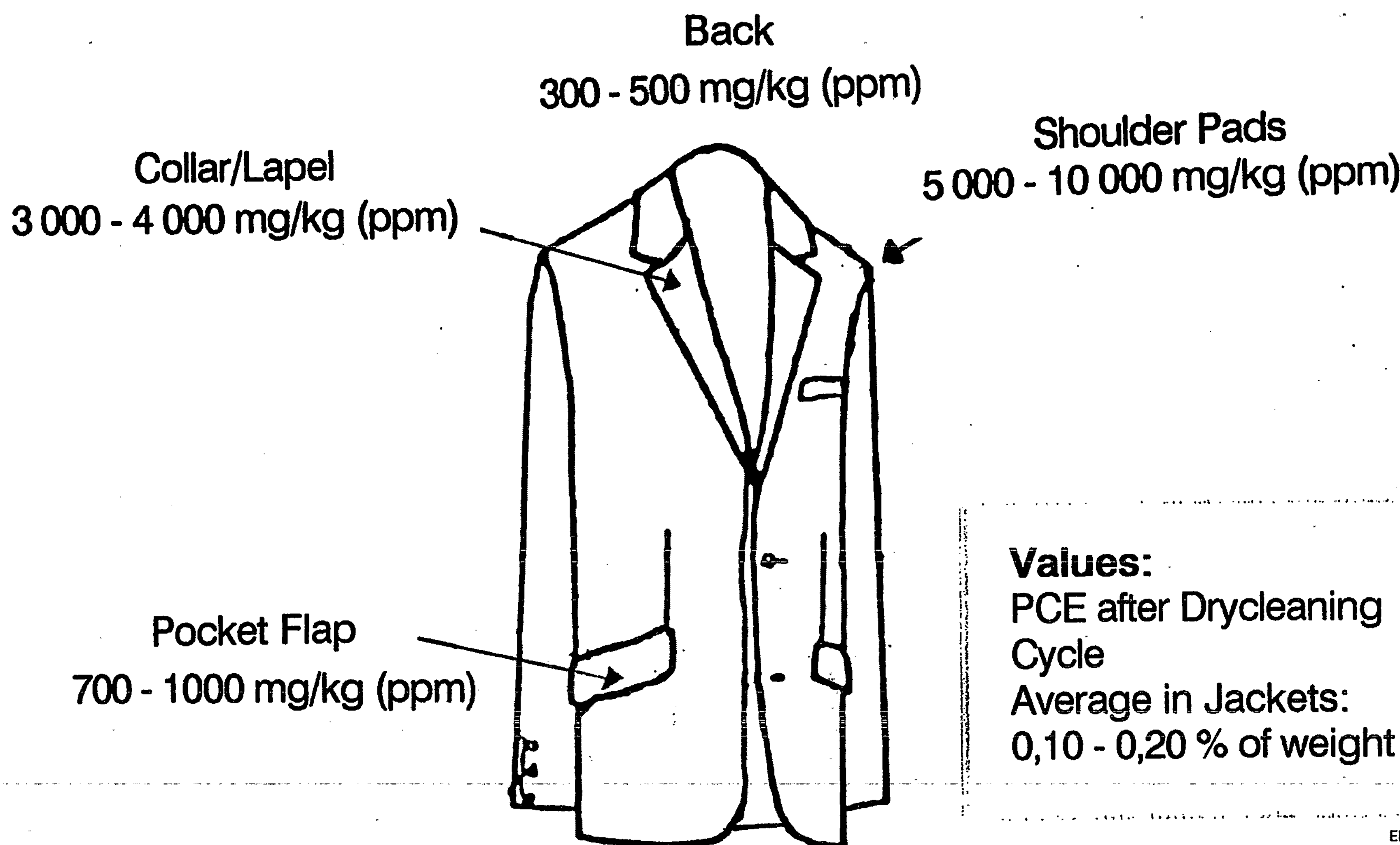
4.2. Retention of Different Fibres/Textiles



EPA 50 KU

EPA Roundtable | **Residual Reduction** | Institute Hohenstein

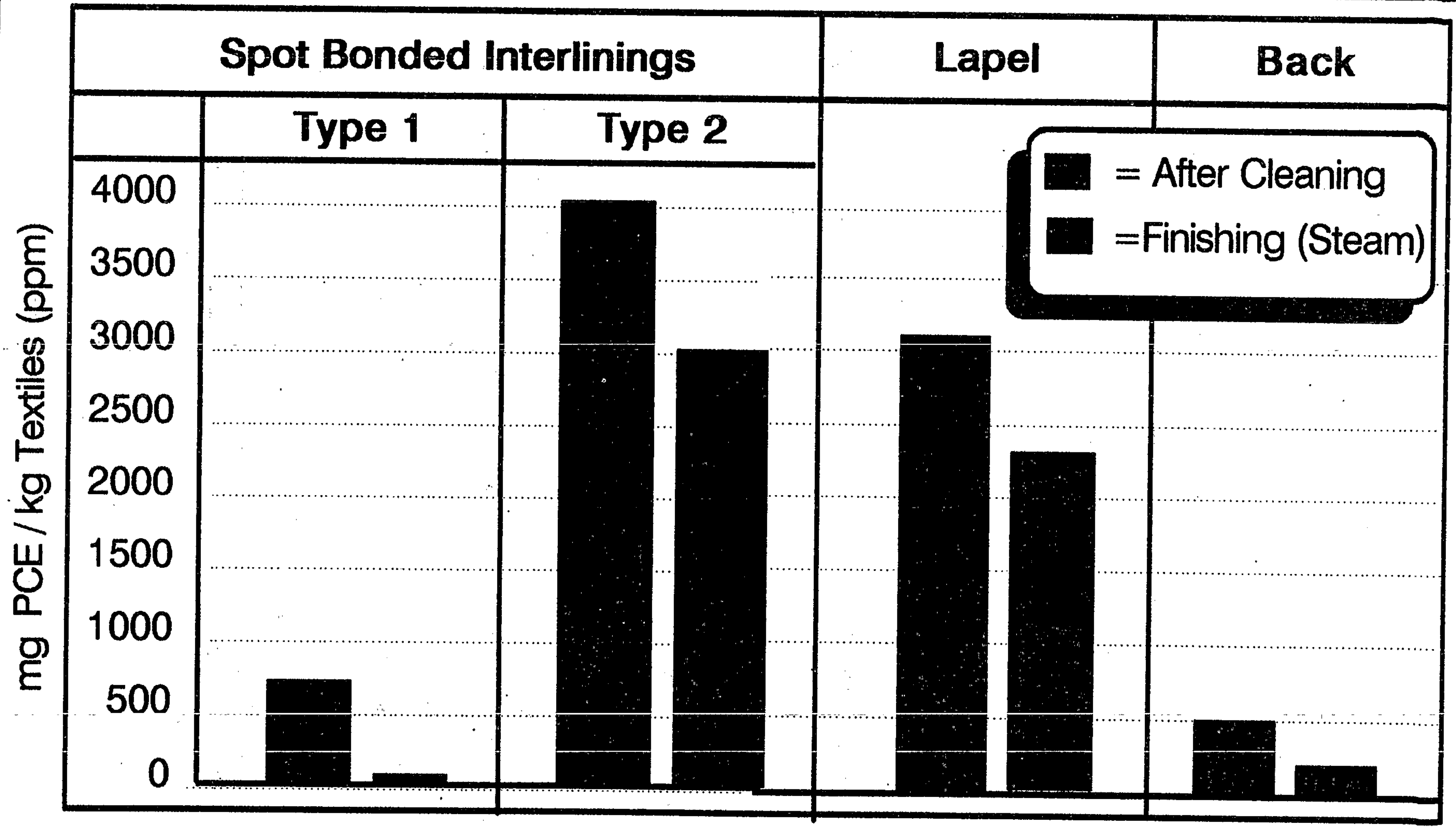
5.1 Distribution of Perchloroethylene



Values:
PCE after Drycleaning Cycle
Average in Jackets:
0,10 - 0,20 % of weight

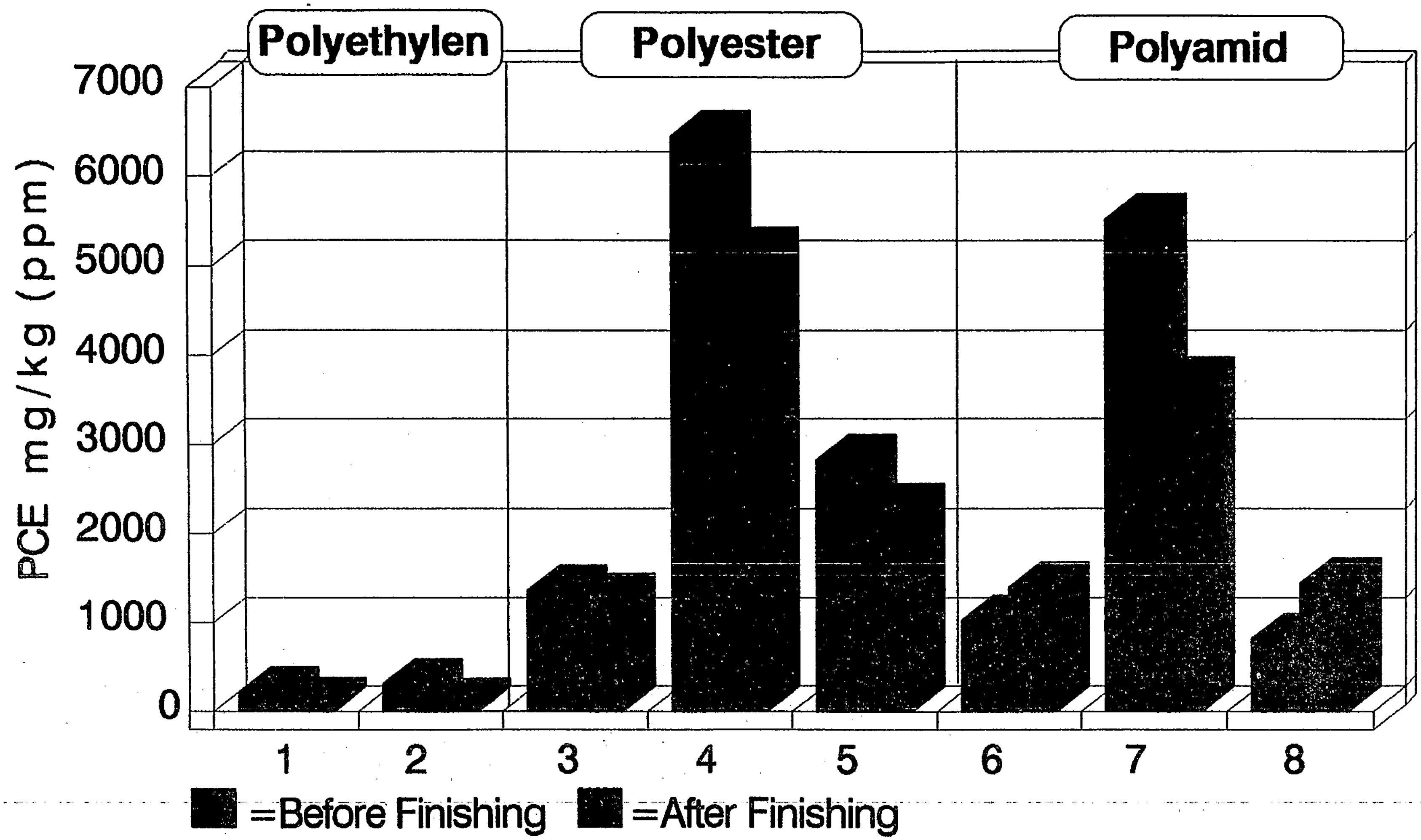
EPA 32 KU

5.2 Residues in Finished Textiles (Examples)



EPA Roundtable | Residual Reduction | Institute Hohenstein

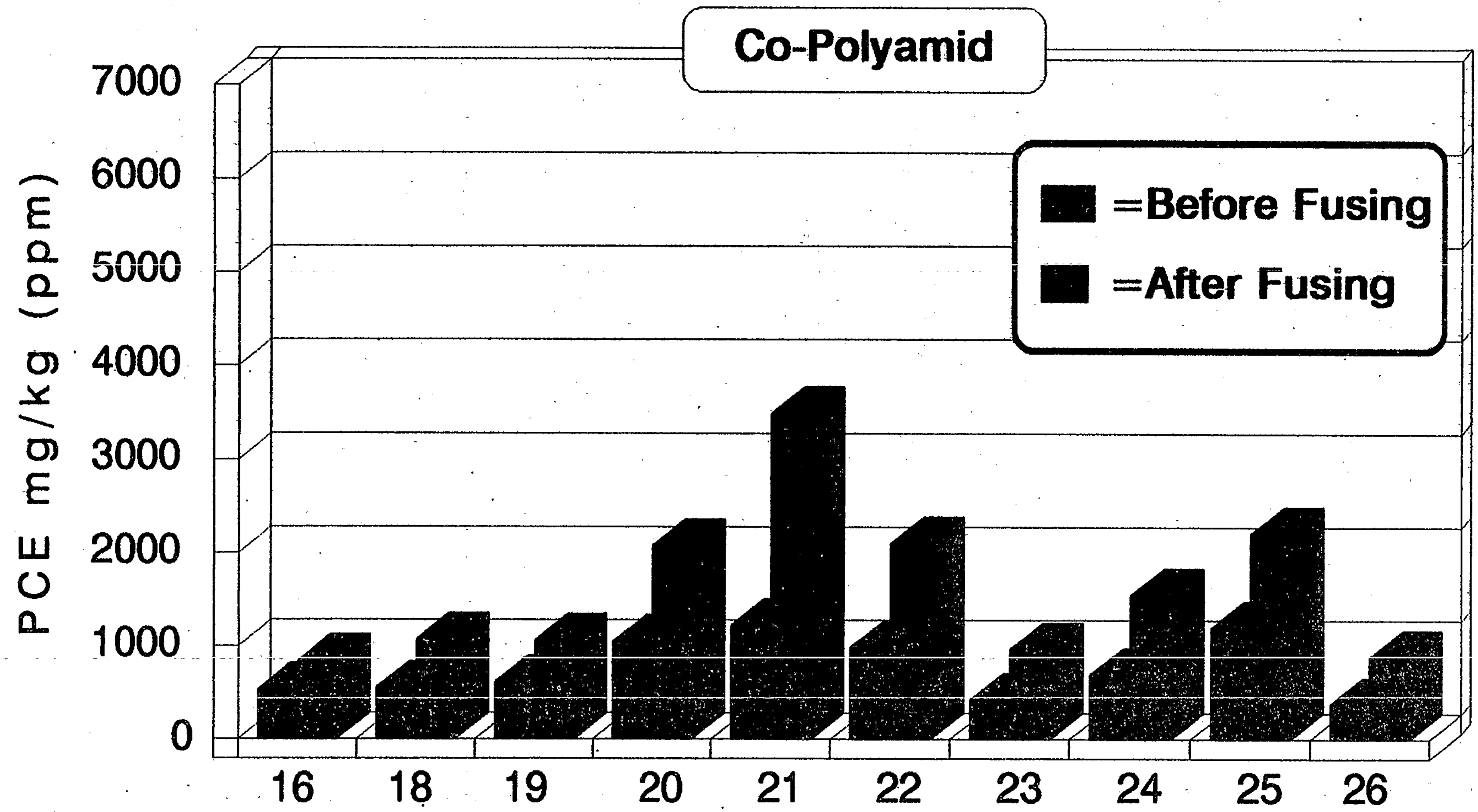
5.3. Retention of Fused Interlinings



EPA 42 KU

EPA Roundtable	**Residual Reduction**	Institute Hohenstein

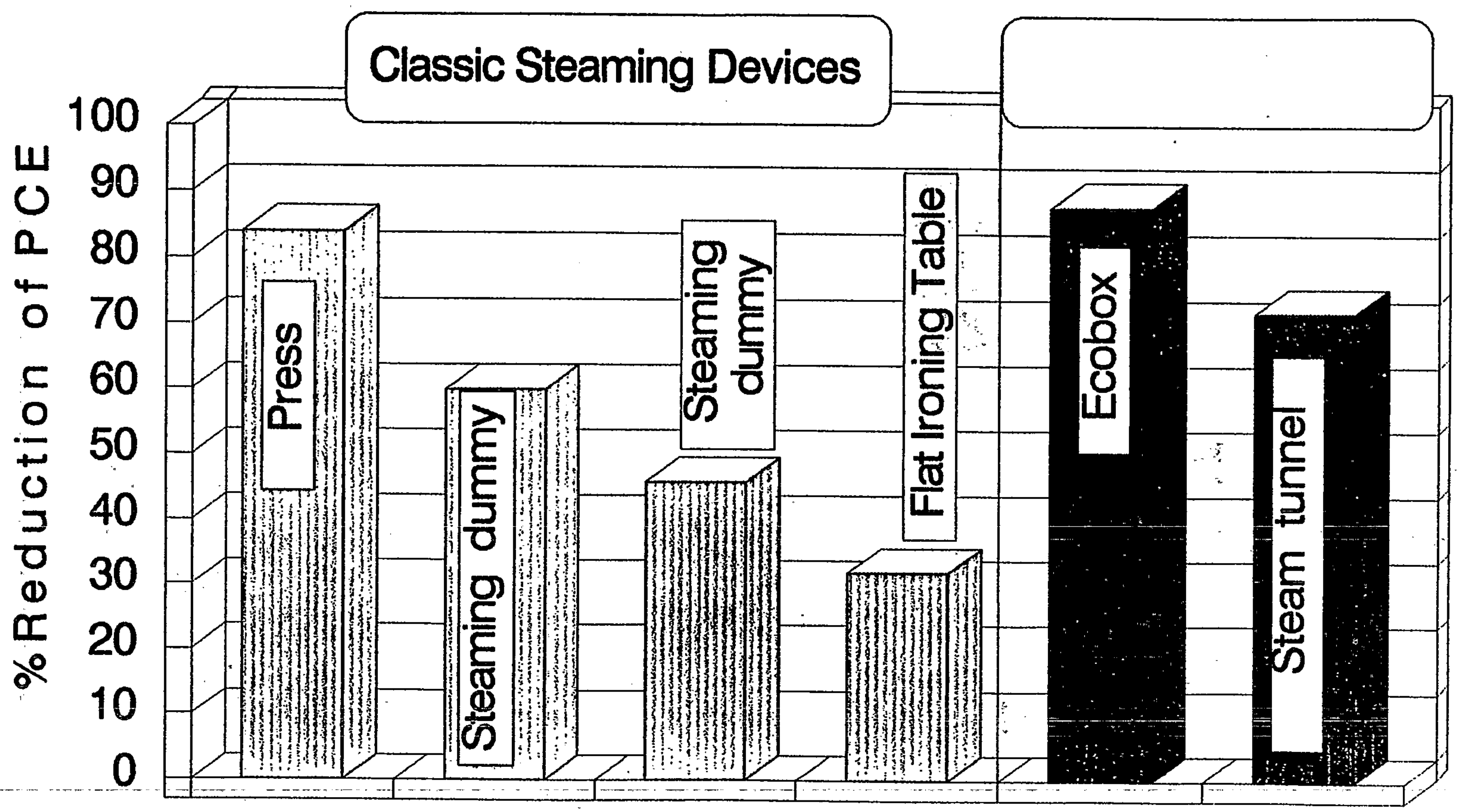
5.4. Retention of Fused Interlinings



EPA 43 KU

EPA Roundtable	**Residual Reduction**	Institute Hohenstein

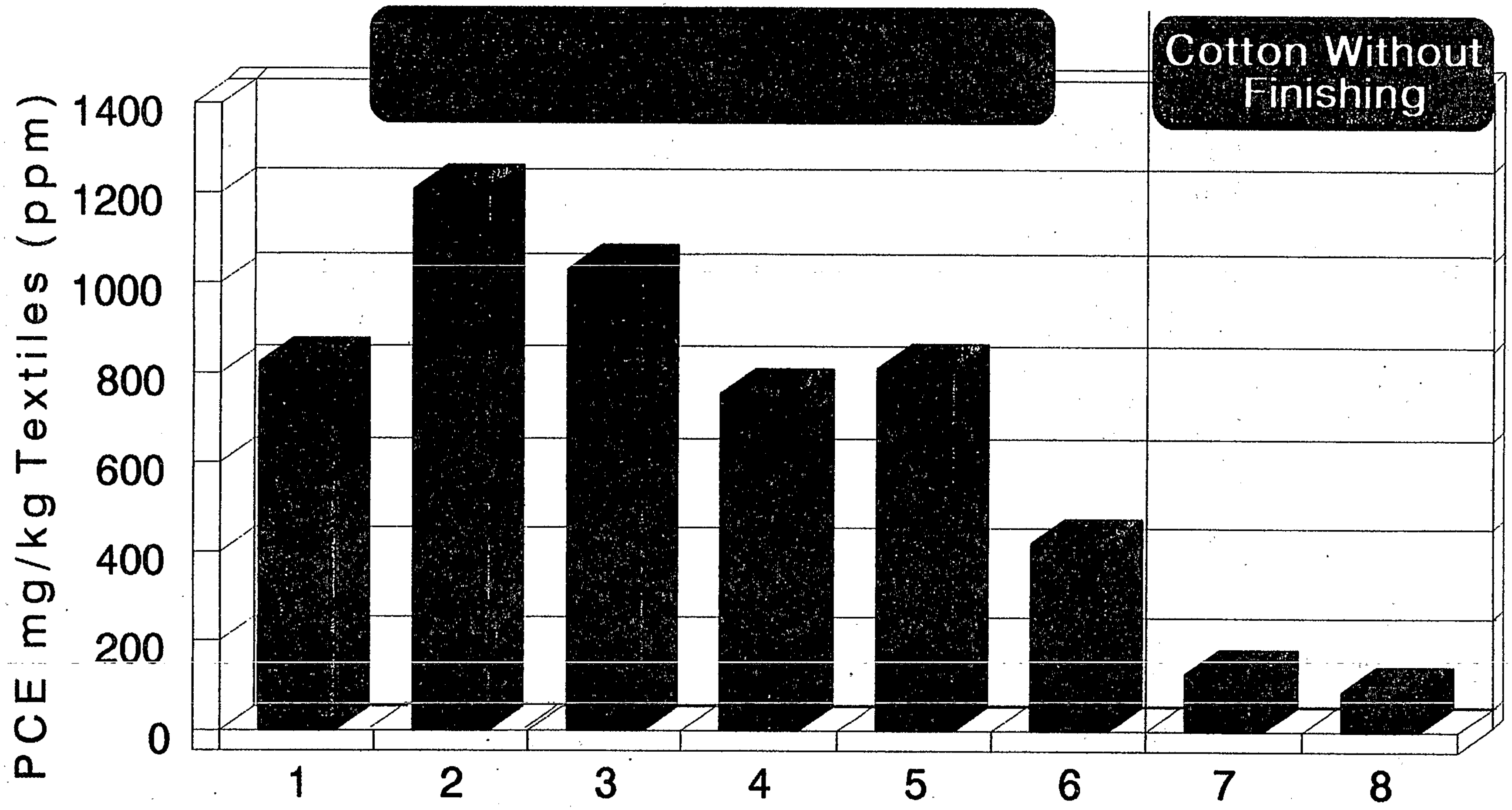
6 Finishing Treatments



EPA 44 KU

EPA Roundtable | **Residual Reduction** | Institute Hohenstein

7 Retention of Finish on Cotton



EPA 47 KU

EPA Roundtable | **Residual Reduction** | Institute Hohenstein

27. / 28.05.1992

Prepared for Discusssion

Dioxins and Furans

EPA59 KU

EPA Roundtable	Josef Kurz	Institute Hohenstein

Survey

Dioxins and Furan

1. Fundamental Information
2. Research Programs
3. Chemistry of Dioxins and Furans
4. Chemistry of Dioxin
5. Forming of Congeners
6. Toxicity Equivalents

7.1. Pathes
7.2. Fundamental Consideration
7.3. Fundamental Consideration (Continued)
8.1. Screening Tests
8.2. Screening Tests (Continued)

9. Results
10. Results (Continued)
11. Comparison
12. Conclusion
13. Distillation Tests and Results (without dirt)
14. Dioxins / Furans in CFC / White Spirit
15. Further Conclusions
16. Origin of Dioxin and Furan Burden
17. Final Conclusion
18. Sources
19. Removal of PCDD / F by Drycleaning
20. Further Experiments: Redistillation

EPA58 KU

1

Fundamental Information

1. Origin of Discussion
   The University of Bayreuth (Germany, Bavaria) discovered dioxins and furans in the residue of drycleaning stills.

2. Publication
   The research results were published by R.Fuchs and O. Hutzinger in ECOMED 2 (1) 16- 17 (1990).

3. Decisions
   The UBA (Umweltbundesamt) decided to have investigated the problems fundamentally and asked the Ministry of Research and Technology (BMFT) to finance the necessary research works.

4. Performance
   The University of Bayreuth (O. Hutzinger) and Institute Hohenstein (J. Kurz) investigated the problems in cooperation.

(EPA D/F 1KU)

2	*Research Programs*

There are 2 Research Programs in Cooperation of the University of Bayreuth and Institute Hohenstein.

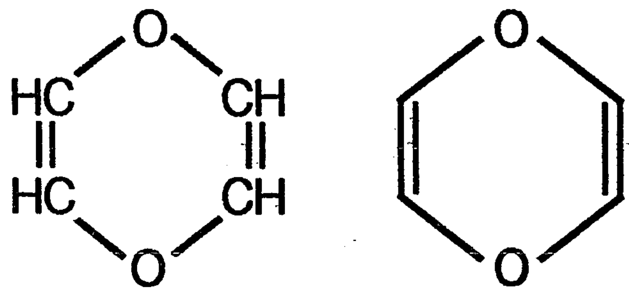
1. Avoidance of dioxin containing residues during industrial production under use of chlororganic compounds.

   Financing: Ministry of Research and Technology (BMFT)
   Coordinator: Dr. W. Drechsler, Umweltbundesamt (UBA)
   This program is finished and ready for publication.

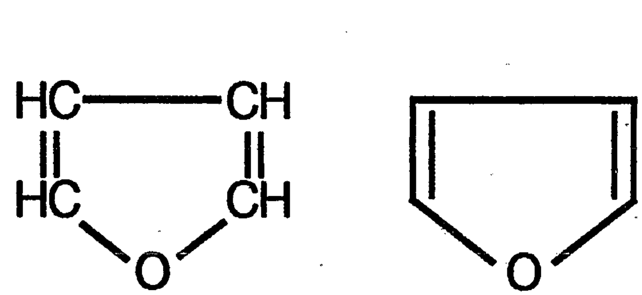
2. Possible emission pathes of dioxins / furans out of drycleaning machines.
   Coordinator: Dr. H. Brackemann, Umweltbundesamt (UBA)
   This program has been started on Februar 1992 and will be finished on January 31 th, 1993.

(EPA D/F 2 KU)

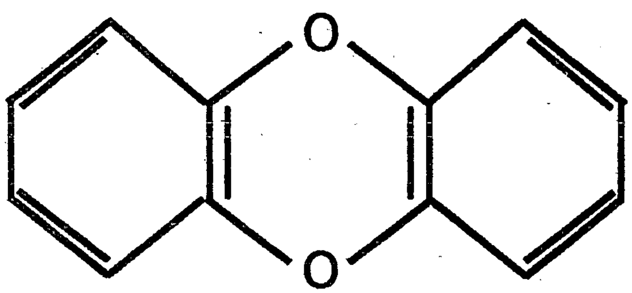
3 *Chemistry of Dioxins and Furans*



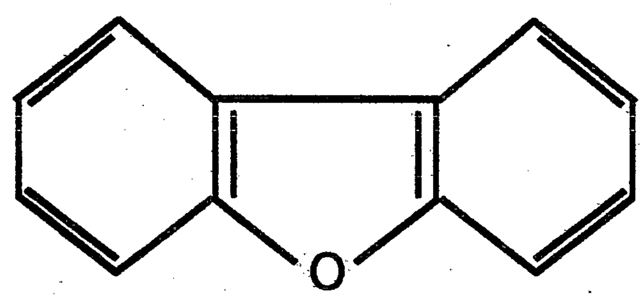
Dioxin



Furan



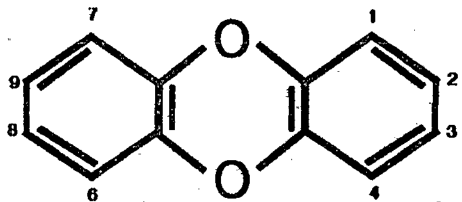
Dibenzo - Dioxin (DD)



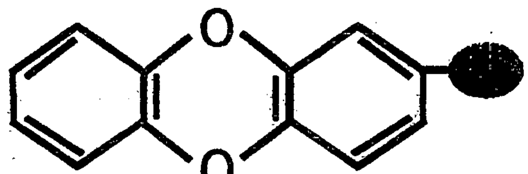
Dibenzo - Furan (DF)

(EPA D/F 3 KU)

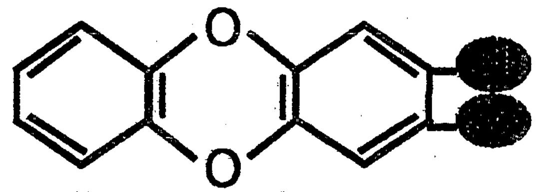
4 *Chemistry of Dioxin*



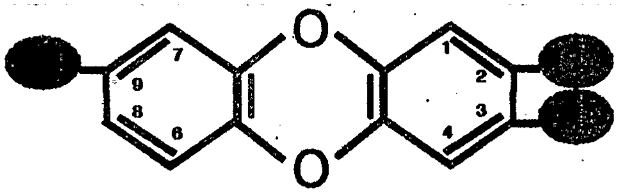
Dibenzo - Dioxin (DD)



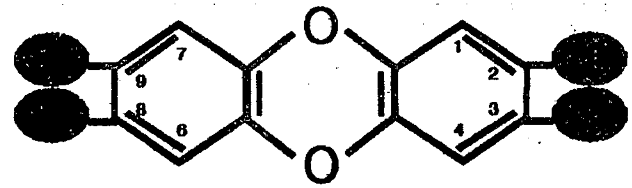
Monochloro - Dibenzo_ Dioxin (MCDD)



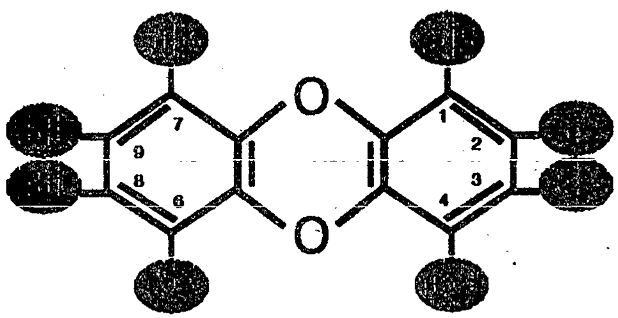
Dichloro - Dibenzo - Dioxin



Trichloro - Dibenzo -Dioxin



2,3,7,8, Tetrachloro - Dibenzo- Dioxin (TCDD, Seveso - Dioxin)



Octachloro - Dibenzo - Dioxin

In total there are
75 dioxins and 135 furans.

(EPA D/F 4 KU)

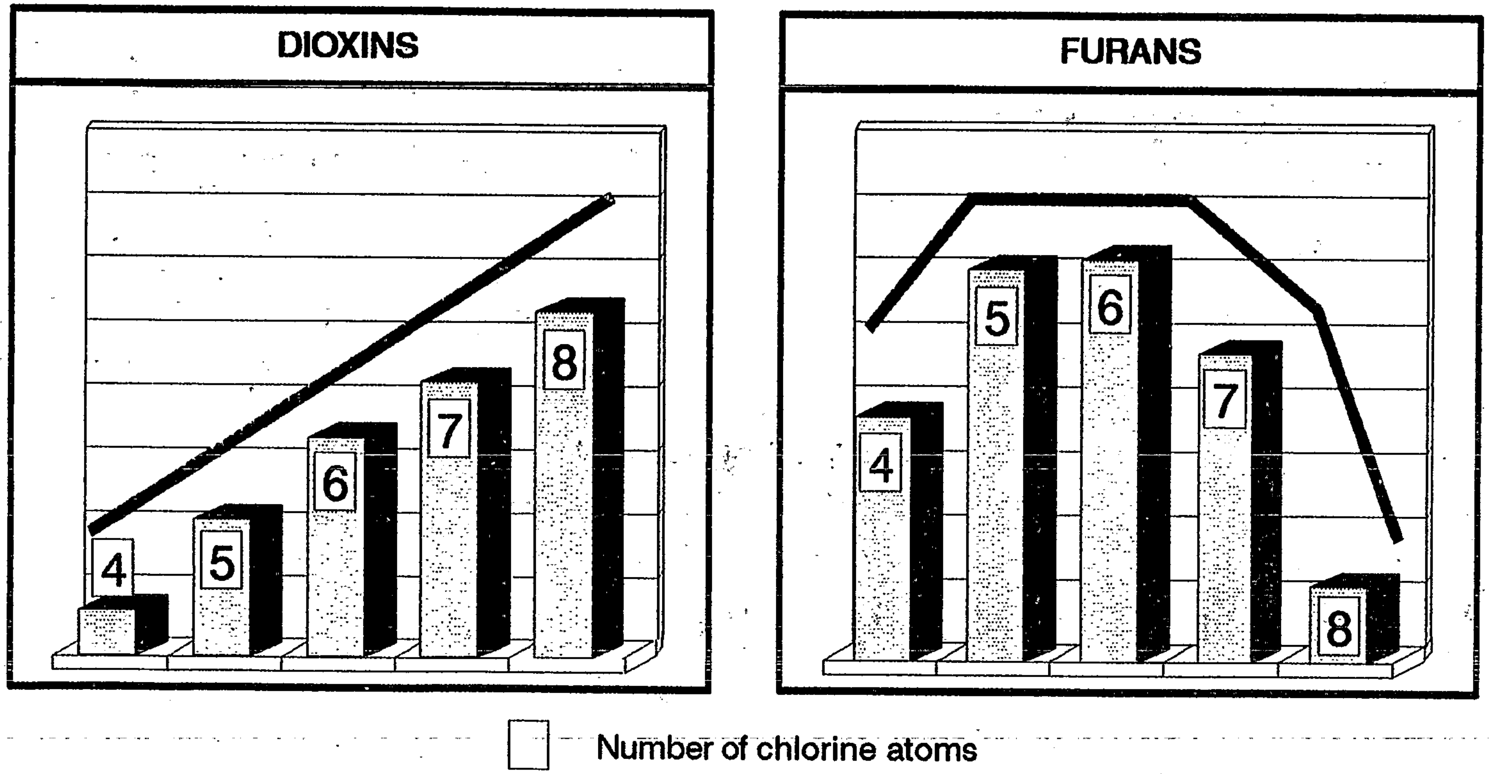
EPA Roundtable | **Institute Hohenstein**

5

Forming of Congeners

Definition: Congener means: "Produced together" = unavoidable forming of dioxins / furans with different number and position of chlorine atoms

Example: INCINERATION OF GARBAGE

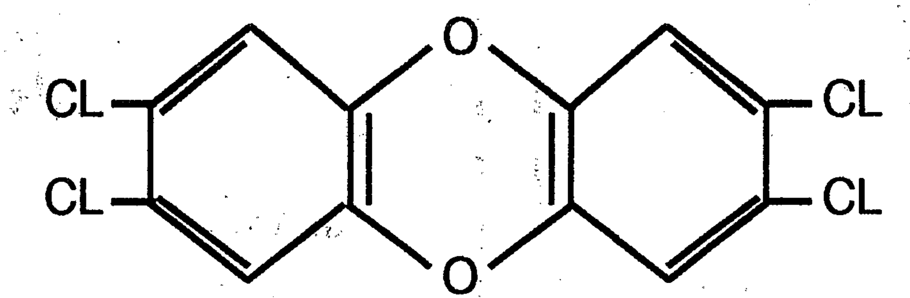


(EPA1 Pi)

6 *Toxicity Equivalents*

Fundamentals: The congeners of dioxin and furan hold different degrees of toxicity.

- The degree of toxicity is expressed by a "Toxicity equivalent (TE)"
- The base is seveso - dioxin (=2,3,7,8, Tetrachloro - Dibenzo - Dioxin TCCD)

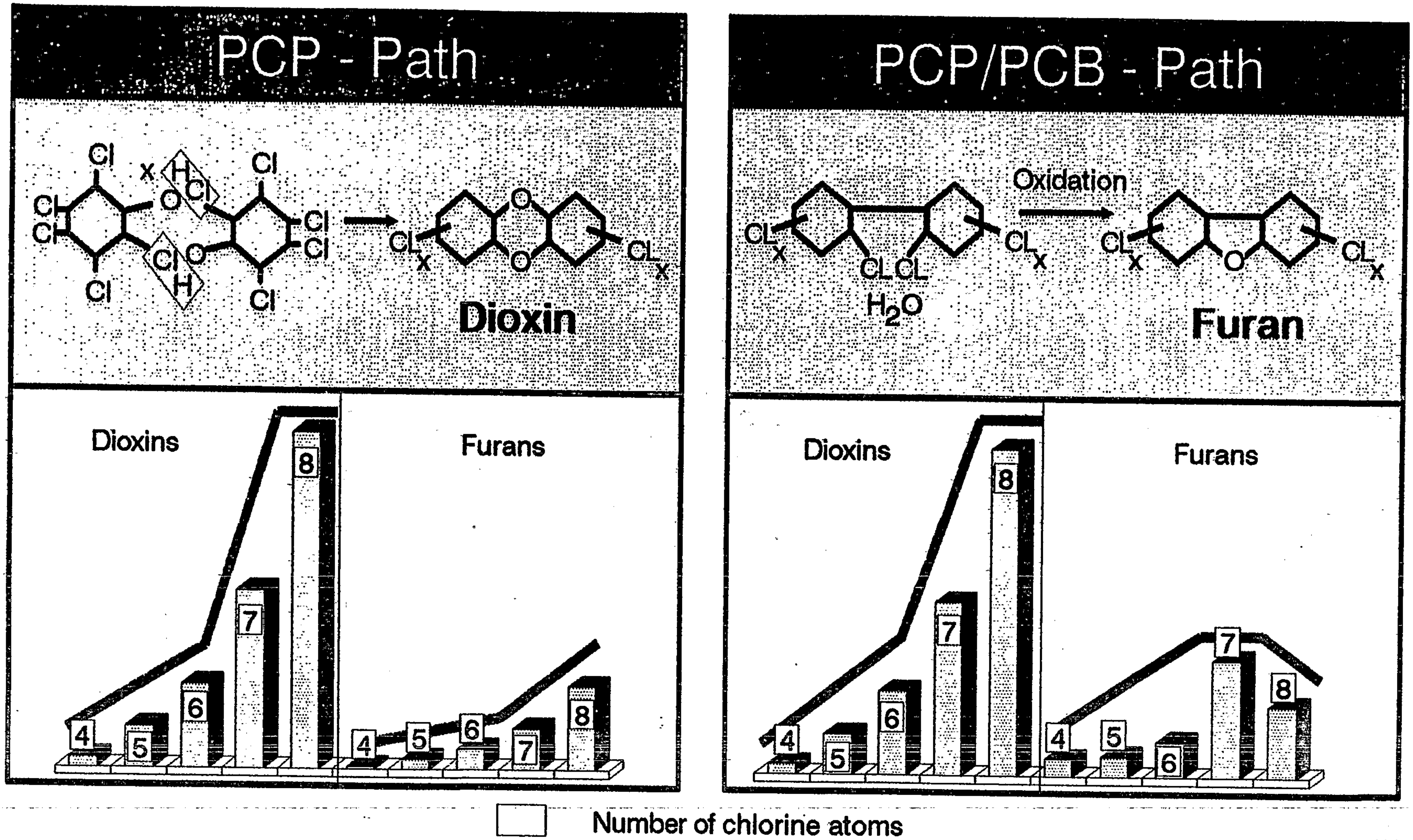


Seveso Dioxin

2,3,7,8, Tetrachloro-Dibenzo-Dioxin TCDD

(EPA D/F 6 KU)

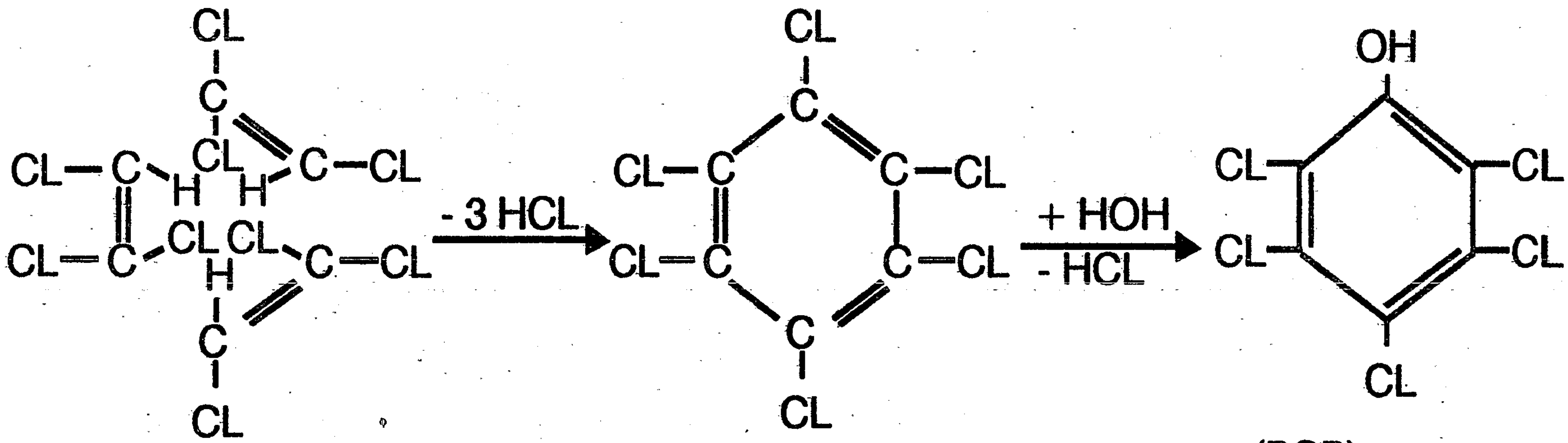
7.1. *PATHES*



(EPA9 Pi)

EPA Roundtable — Institute Hohenstein

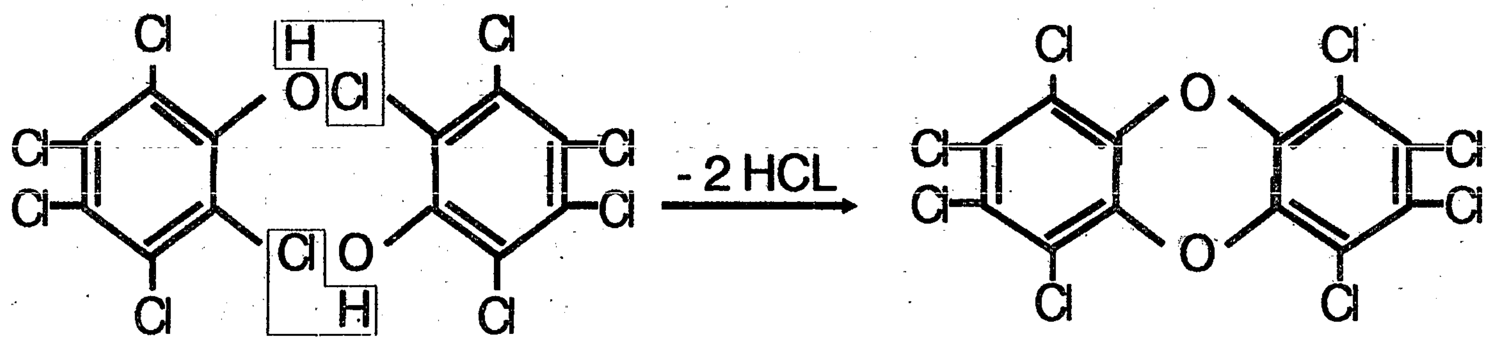
7.2. *Fundamental Consideration*



Trichloroethylene

Hexachlorobenzol

(PCP)
Pentachlorophenol



(EPA D/F 7-2KU)

7.3. *Fundamental Considerations*

Possible transforming into drycleaning

- Perchloroethylene could be dechlorinated to trichloroethylene during destillation in the still

- Trichloroethylene could be transformed to dioxin via hexachlorobenzol and pentachlorophenol

Conditions for forming dioxins in the still:

- Presence of Perchloroethylene / Trichloroethylene
- Alkalinity
- High temperature
- Time
- Perhaps: Catalysts, i.e.: metal ions, sorptiv substances for activating the reaction components

(EPA D/F7-3 KU)

EPA Roundtable | Institute Hohenstein

8.1. *Screening Tests*

Expert of Institute Hohenstein took samples in:

- Drycleaning plants
  (machines with 25 kg capacity and higher, drycleaned goods: normal garment, workwear, rugs, carpets)
- Drycleaning shops (unit shops)
  with machines less than 25 kg capacity
- Leather and suede cleaners

All samples were taken from the waste barrel, in which the hazardous waste was collected until the next removal by an professional collector.

(EPA D/F 8-1KU)

8.2. *Screening Tests*

In Institute Hohenstein tests were carried out to estimate the conditions of destillation on formation of dioxins and furans.

All samples were analyzed with regard to

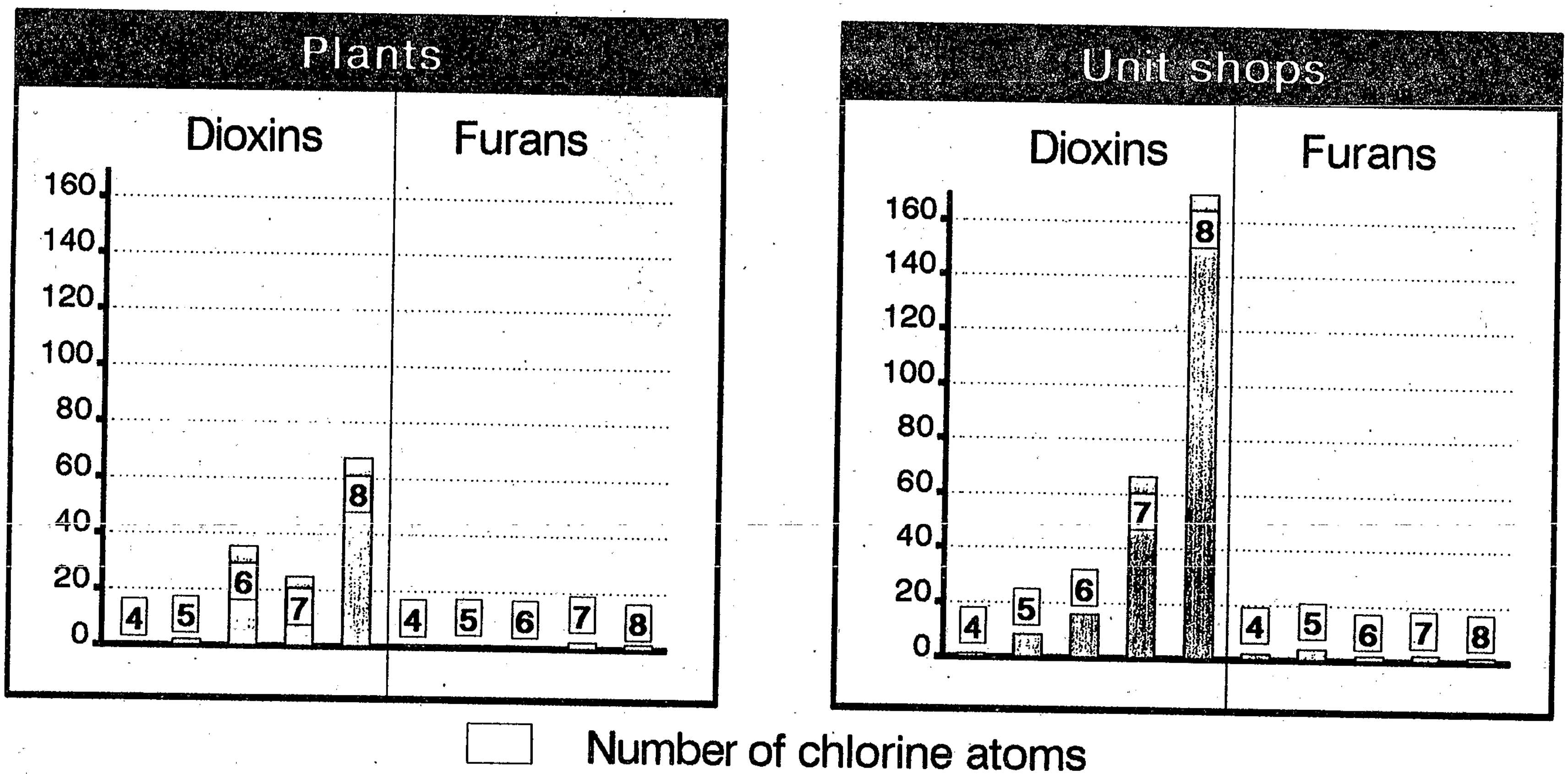
- Dioxins/Furans by the University of Bayreuth
- Dry "content"
- Trichloroethylene
- pH Value

(EPA D/F 8-2 KU)

9

Results

Perchloroethylene machines, distribution of congeners in residues of still average (ppb), drycontent



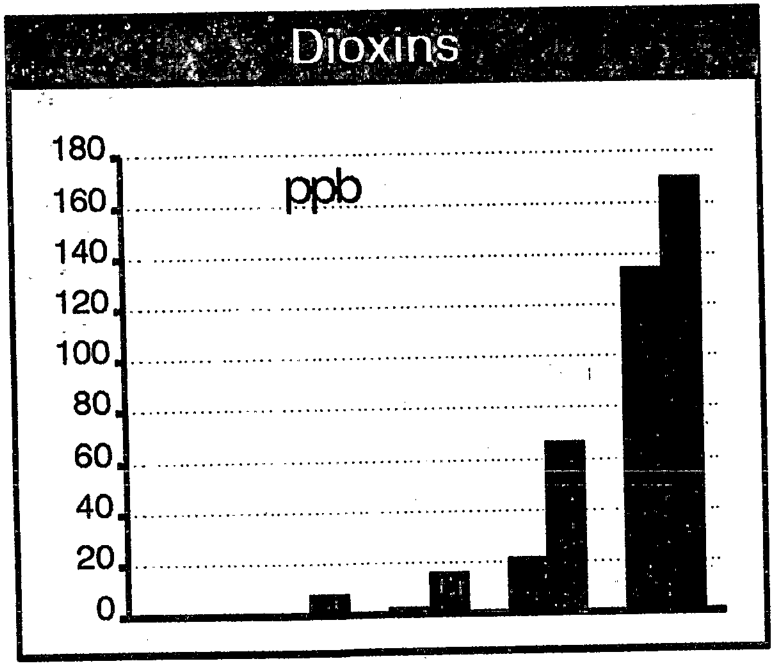
(EPA25 Pi)

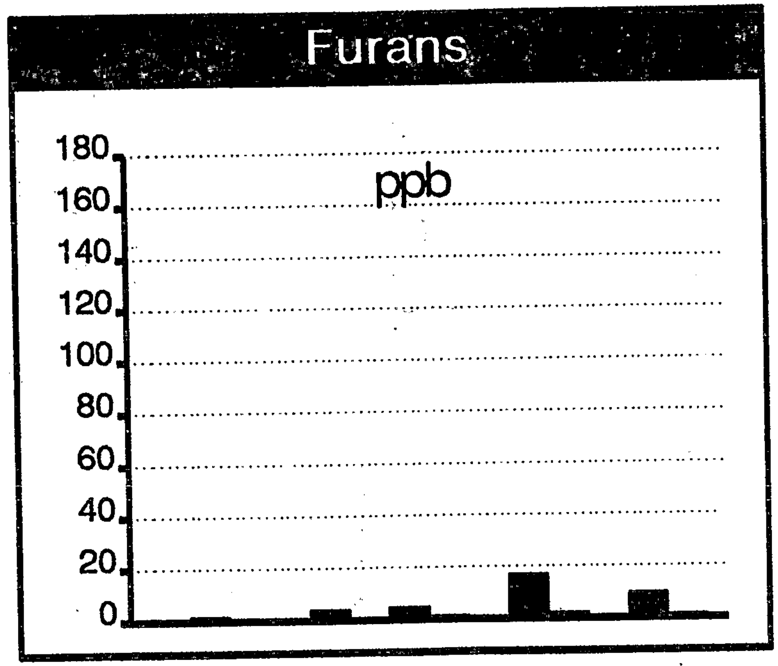
10

Results

Leather and suede cleaners in comparison with drycleaning shops

Perchloroethylene machines, distribution of congeners in residues of still, average





Leather and suede cleaners

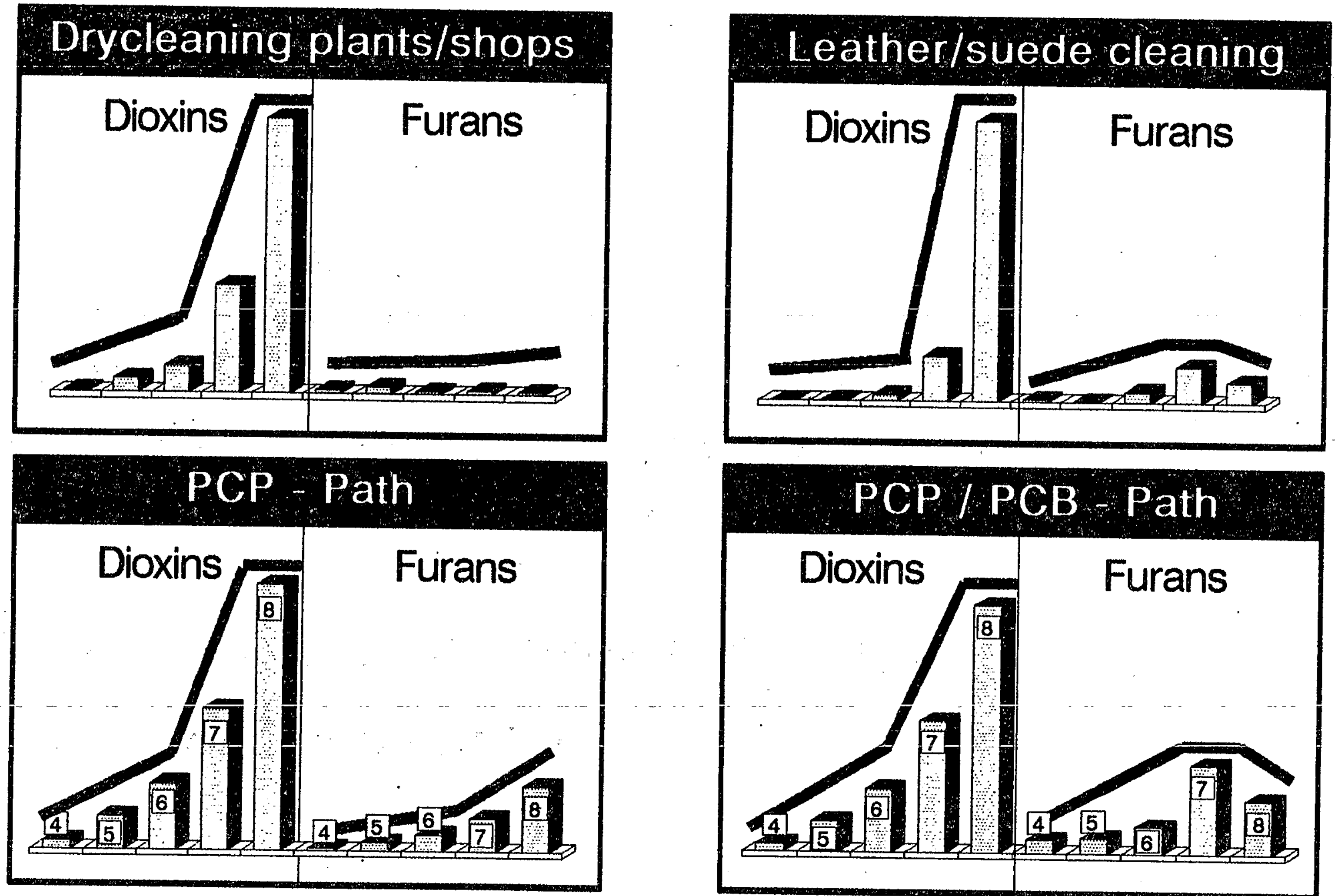
drycleaning shops

Number of chlorine atoms

(EPA24 Pi)

11

Comparison



☐ Number of Chlorine Atoms

(EPA26 Pi)

EPA Roundtable

Institute Hohenstein

12

Conclusion

Drycleaning plants/shops:

- dioxins/furans are formed via pentachlorophenol (PCP)

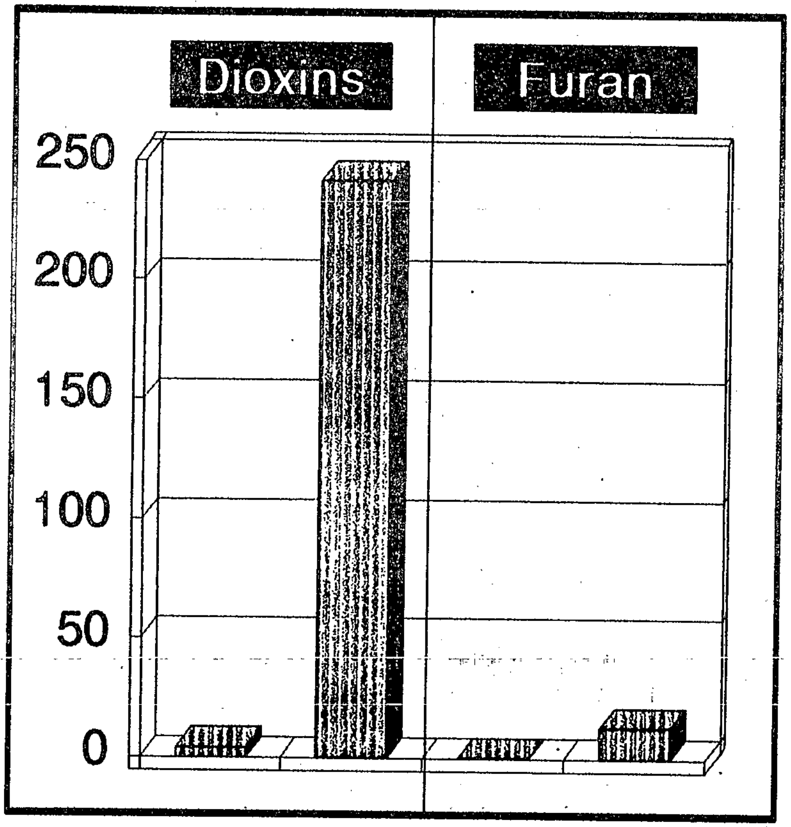
Leather and suede cleaners:

Additionally to the PCP-paths, there is an influence of polychlorinated biphenyls (PCB).

(EPA D/F 12 KU)

13 *Distillation Tests and Results (without dirt)*

PCDD / F(average) in residues of still in ng/g (ppb) drycontent



■ Distillation

Distillation conditions:

Trichloroethylene
Perchloroethylene
Tea powder
Sodium carbonate
Ferric chloride
Water
Temperature 190 °C 374 °F
Duration: 48 h

<u>Comparison</u>

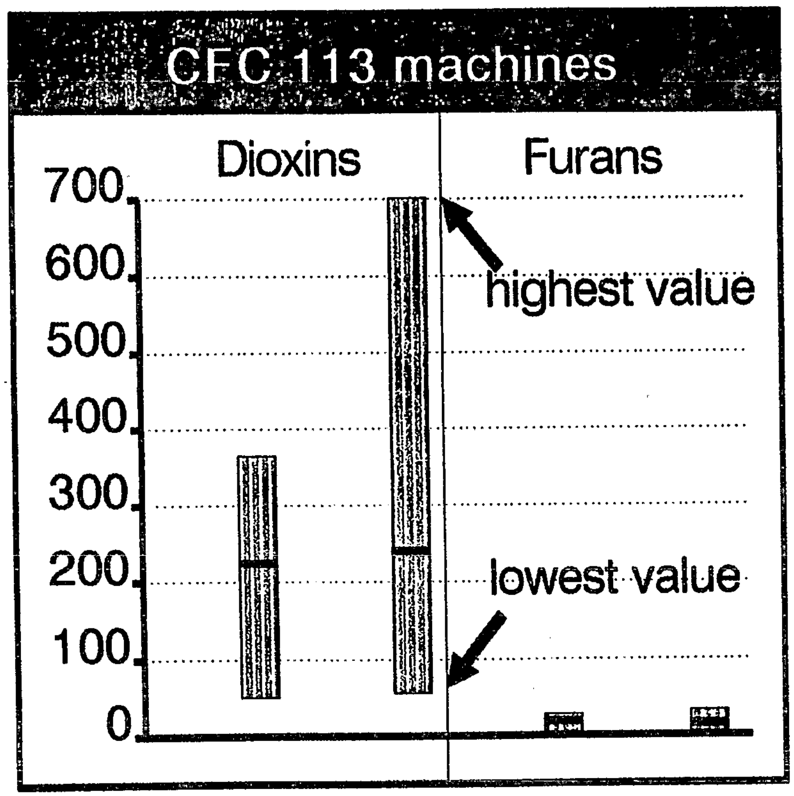
■ Drycleaning shops

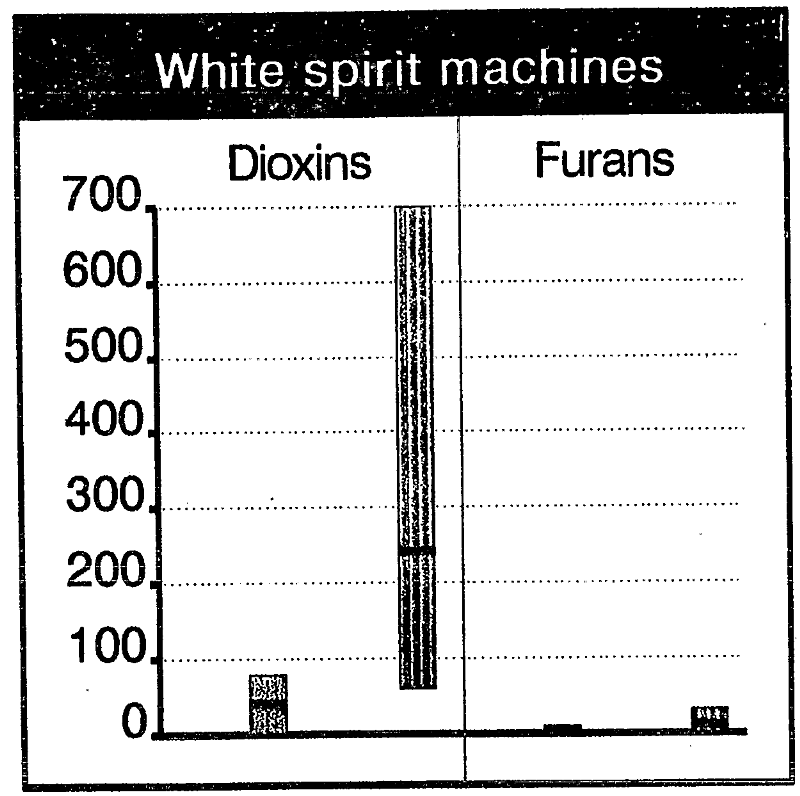
(EPA22 Pi)

14

Dioxins / Furans in CFC / White Spirit

PCDD / F(average) in residues of still in ng/g (ppb), drycontent





Comparison: Perchloroethylen machines — average

(EPA21 Pi)

15

Further Conclusions

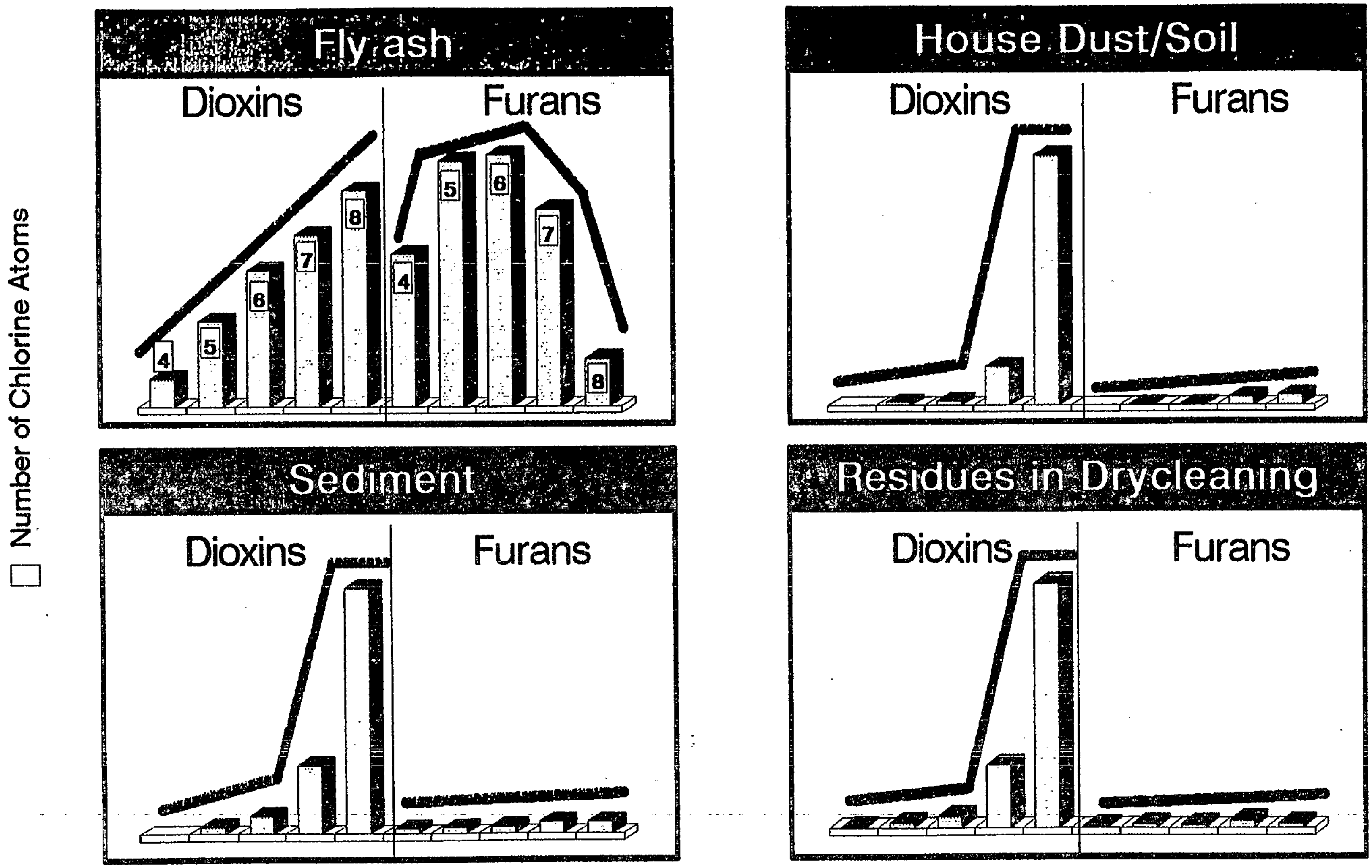
1. It was impossible - even under extreme conditions - to form dioxins/furans in the still of a drycleaning machine. The destillation conditons cannot be reason for the formation of dioxins/furans.

2. Dioxins/furans are found in residues of CFC and white spirit stills. That means, both can be found in absence of perchloroethylene.

Question: Where do they come (from/occur)?

(EPA D/F 15 KU)

16 Origin of Dioxin and Furan Burden



(EPA7 Pi)

EPA Roundtable | Institute Hohenstein

17

Final Conclusions

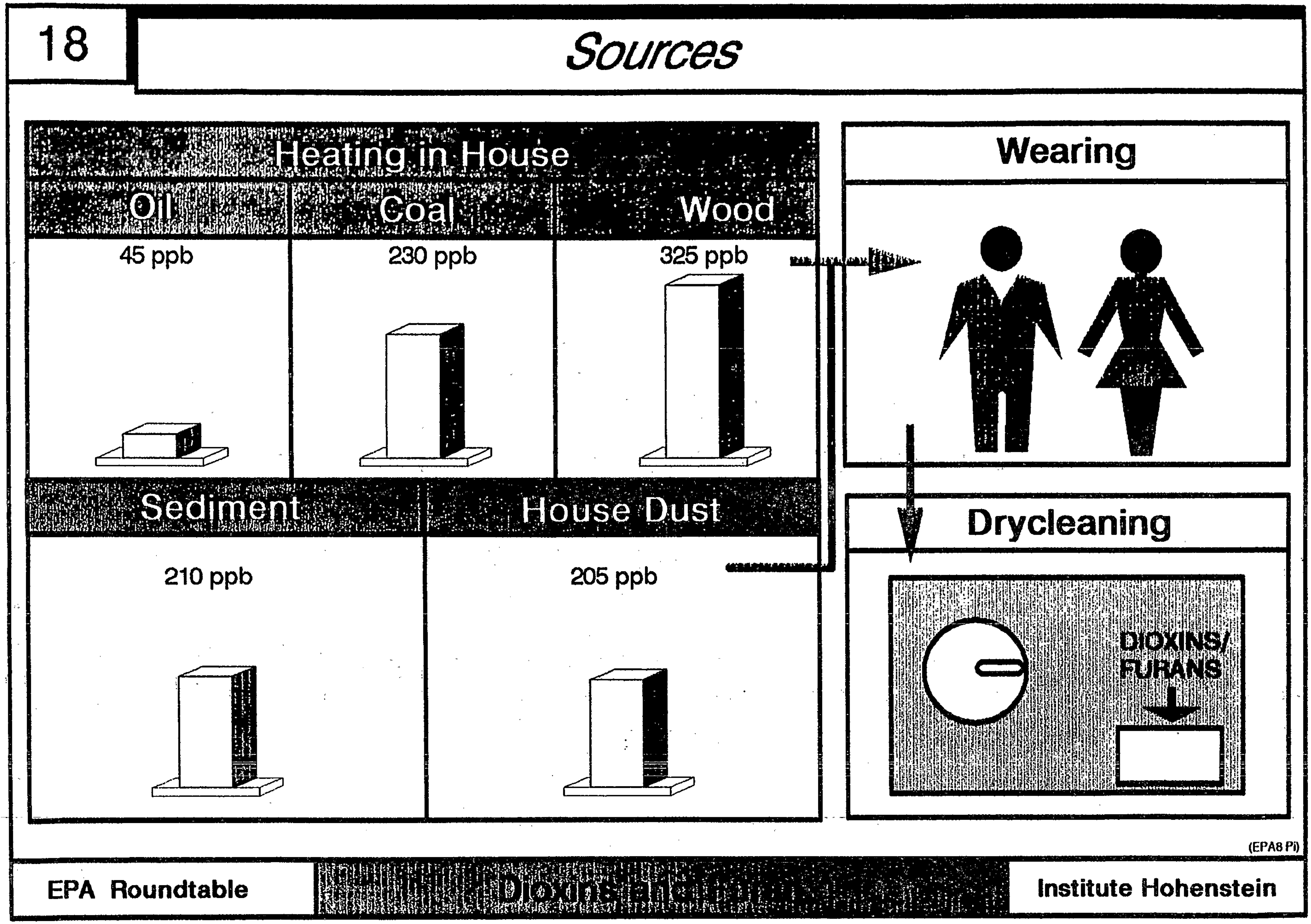
Dioxins and furans in the residue of drycleaning stills are caused by the dirt, removed out of the cleaned textiles.

Dioxins and furans are not formed by transformation of perchloroethylene within the stills.

The formation of dioxins and furans is independent of the type of solvent; also in CFC 113 and white spirit dioxins and furans were found.

Dioxins and furans were only found in presence of dirt.

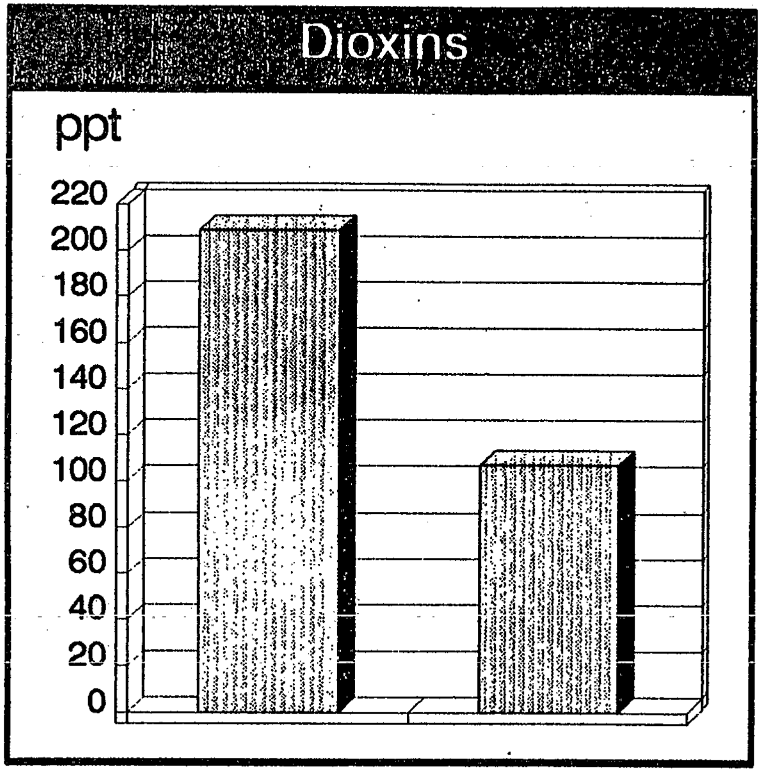
(EPA D/F 17 KU)

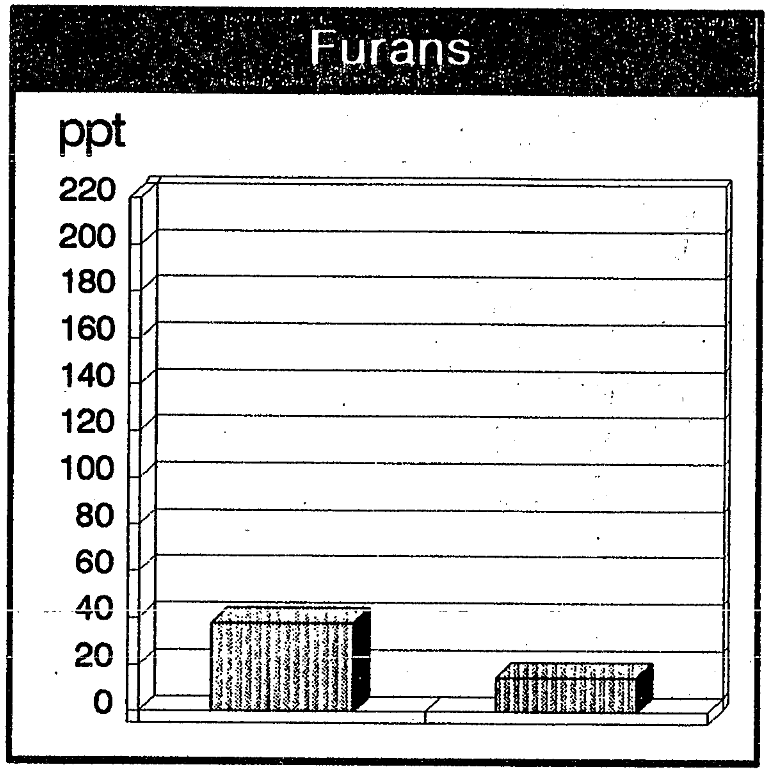

18
Sources
Heating in House
Oil
Coal
Wood
45 ppb
230 ppb
325 ppb
Sediment
House Dust
210 ppb
205 ppb
Wearing
Drycleaning
DIOXINS/
FURANS
(EPA8 Pi)
EPA Roundtable
Institute Hohenstein

19

Removal of PCDD / F by Drycleaning

Textiles: Cotton shirts





after wearing   after drycleaning

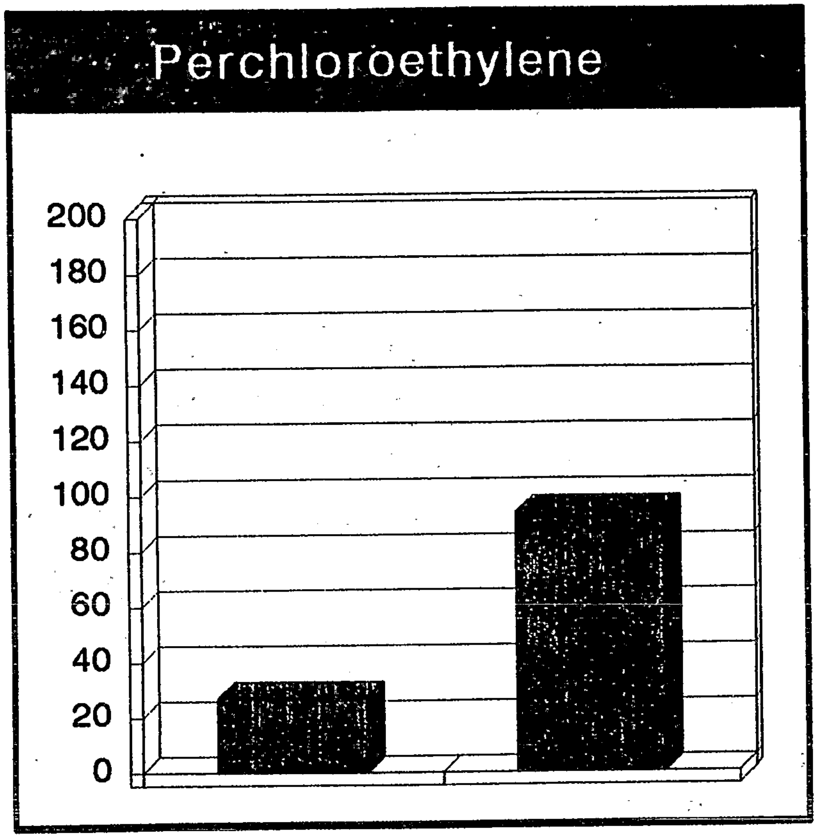
(EPA27 Pi)

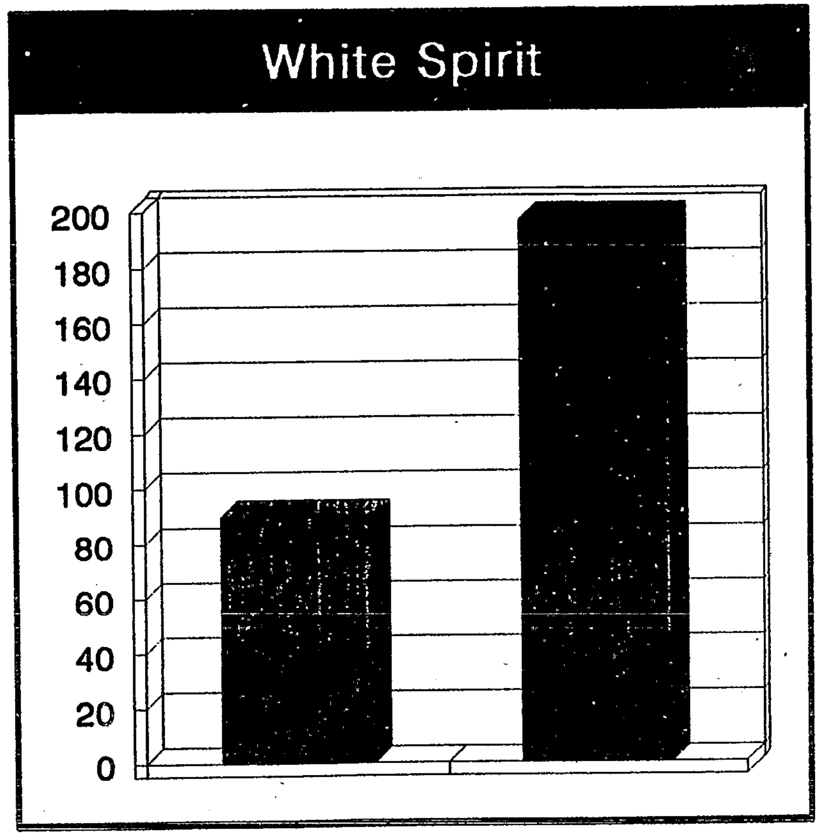
EPA Roundtable   Institute Hohenstein

20

Further Experiments: Redistillation

Increase of PCDD / F in residue of still after redistillation, in ng/g (ppb), drycontent





residue of still   after redistillation (8h; 284° F[140°C]; vacuum)

(EPA23 Pi)

EPA Roundtable   Institute Hohenstein

Submissions from Cynthia Marvin California Air Resources Board

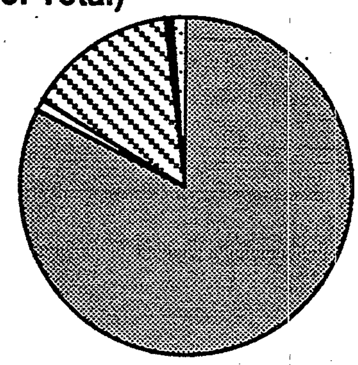
ARB Surveys

Date Sent	Survey Type	Number Sent	Response Rate
April 1992	Original	5,500	32%
June 1992	Hotel/Motel	500	65%
July 1992	Followup	3,700	23%
	Overall response rate		50%

9/92

Breakdown of Solvent Used at Surveyed Facilities

(Percent of Total)



Perc: 84%
CFC-113: <1%
Petroleum Sovents: 15%
1,1,1-TCA: <1%
Other: <1%

Total: 464,000 gallons

9/92

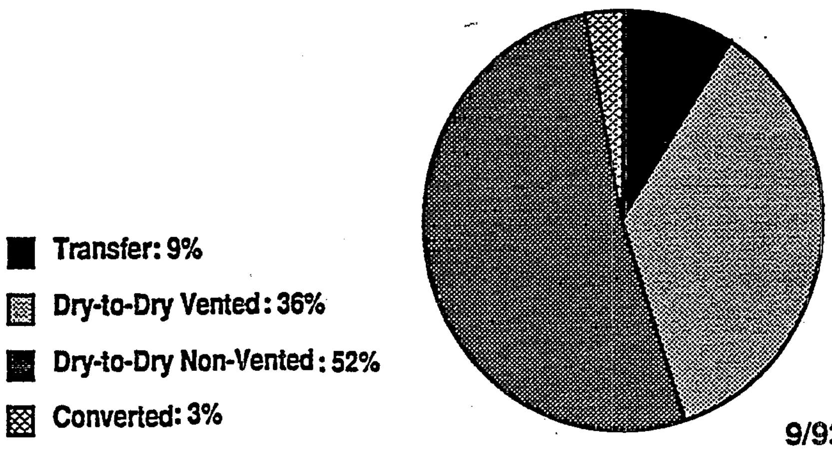
Total Survey Response for Perc Dry Cleaning Operations

Number of Responding Facilities: 1,980

Number of Machines in Use: 2,205

9/92

Types of Perc Dry Cleaning Machines at Surveyed Facilities



9/92

Perc Emission Reduction/Reclamation Devices at Surveyed Facilities

Device Type	Number of Machines
Refrigerated Condenser	1,450
Carbon Adsorber	430
Other	1,090
No Device	100

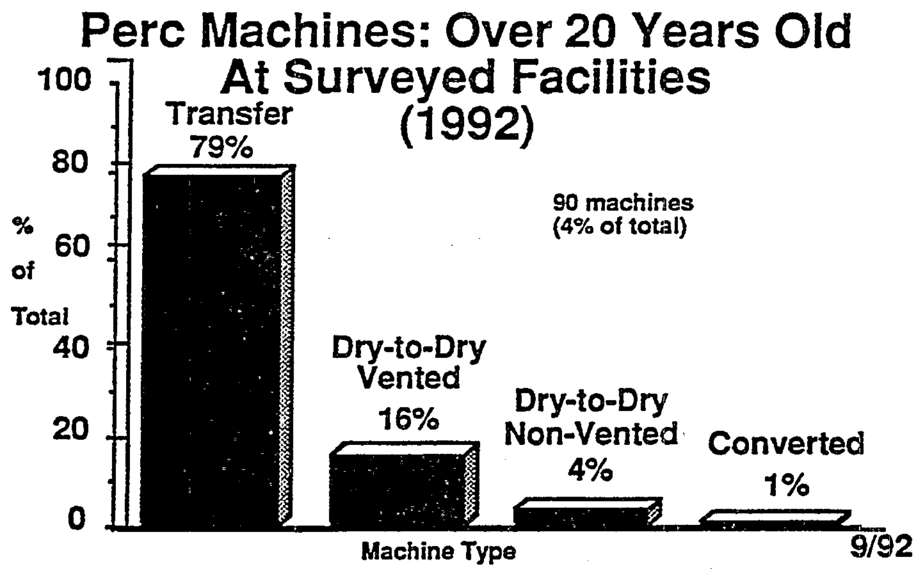
9/92

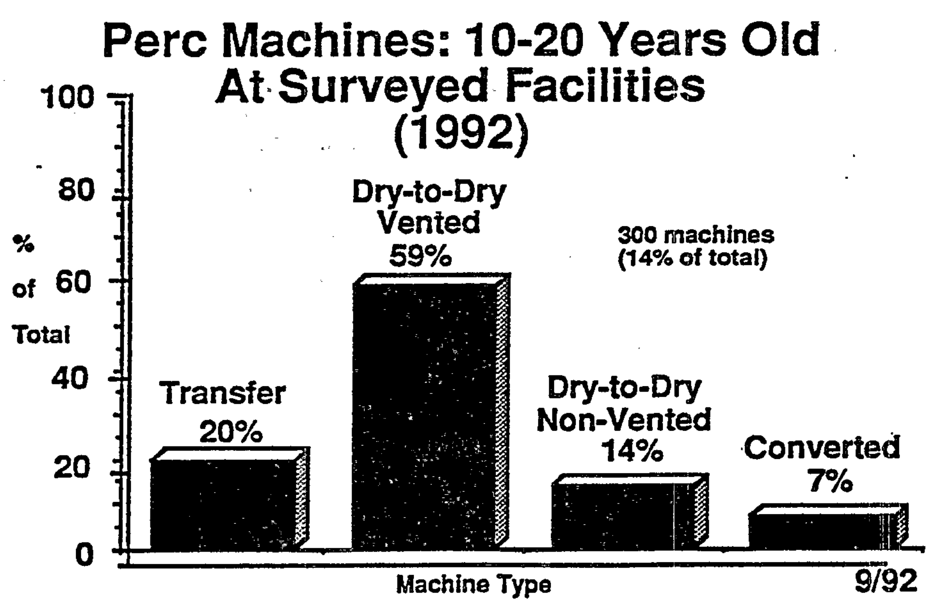
Average Perc Mileage By Machine Type For Surveyed Facilities

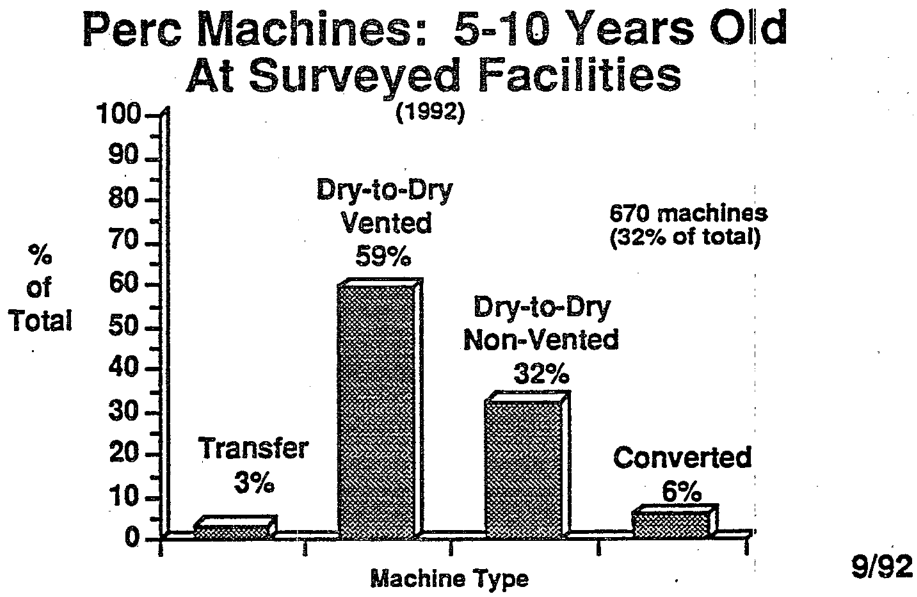
Machine Type	Average Mileage (lbs/gal)	(lbs/drum*)
Transfer	130	6,800
Dry-to-Dry Vented	180	9,400
Dry-to-Dry Non-Vented	370	19,200
Converted	260	13,500

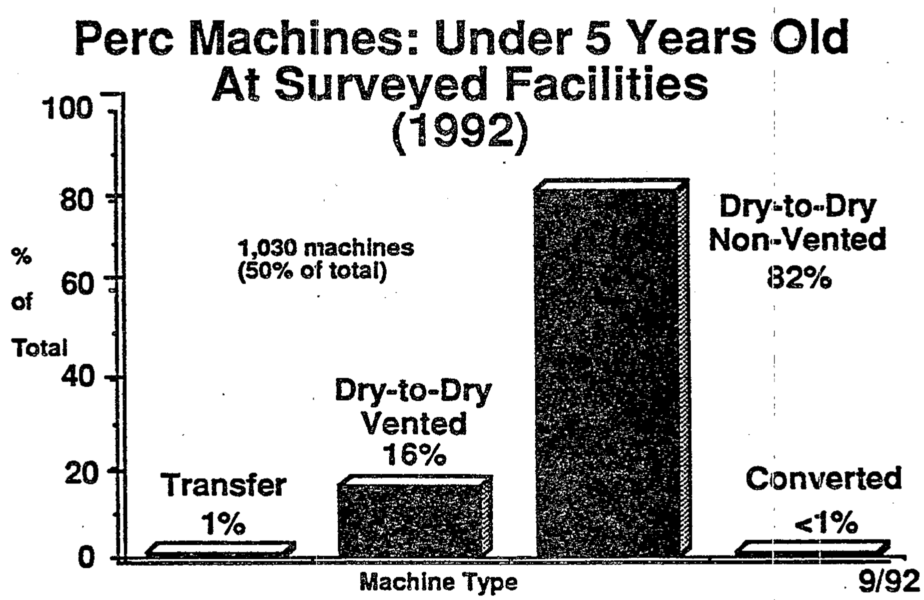
* Based on a 52-gallon drum

9/92

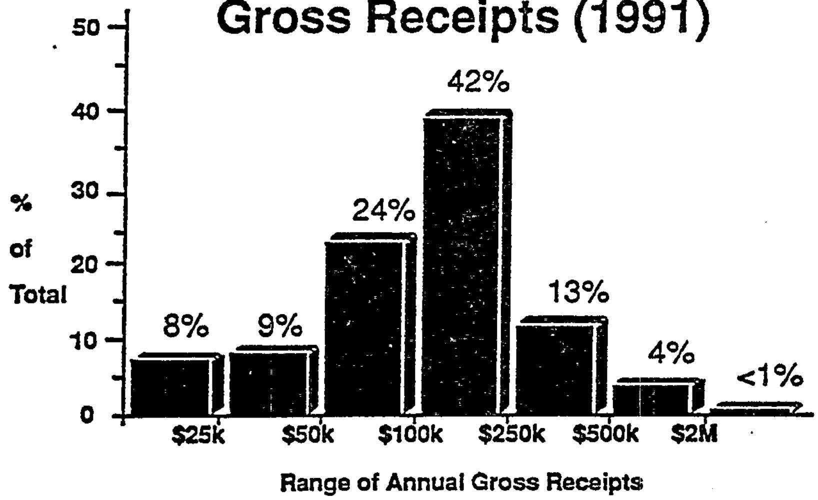

Perc Machines: Over 20 Years Old
At Surveyed Facilities
(1992)
100
80
60
40
20
0
% of Total
Transfer
79%
Dry-to-Dry
Vented
16%
Dry-to-Dry
Non-Vented
4%
Converted
1%
90 machines
(4% of total)
Machine Type
9/92


Perc Machines: 10-20 Years Old
At Surveyed Facilities
(1992)
100
80
60
40
20
0
% of Total
Transfer
20%
Dry-to-Dry
Vented
59%
Dry-to-Dry
Non-Vented
14%
Converted
7%
300 machines
(14% of total)
Machine Type
9/92


Perc Machines: 5-10 Years Old
At Surveyed Facilities
(1992)
100
90
80
70
60
50
40
30
20
10
0
% of Total
Dry-to-Dry Vented 59%
670 machines (32% of total)
Dry-to-Dry Non-Vented 32%
Transfer 3%
Converted 6%
Machine Type
9/92


Perc Machines: Under 5 Years Old
At Surveyed Facilities
(1992)
100
80
60
40
20
0
% of Total
1,030 machines (50% of total)
Dry-to-Dry Non-Vented 82%
Dry-to-Dry Vented 16%
Transfer 1%
Converted <1%
Machine Type
9/92

Surveyed Facilities By Annual Gross Receipts (1991)



9/92

Hotel and Motel Survey: Preliminary Results

- 20 surveyed facilities dry clean on-site
- About 75% have dry-to-dry non-vented machines
- About 25% have dry-to-dry vented machines

9/92

PRELIMINARY DRAFT

HANDOUT FOR ARB STAFF'S SECOND PUBLIC MEETING ON PERC AND DRY CLEANING OPERATIONS

SOURCE TESTING PROGRAM: INFORMATION ON SELECTED FACILITIES
---Preliminary Draft---

FACILITY	TYPE OF EQUIPMENT	MACHINE CAPACITY/ AGE	CLOTHES CLEANED (lbs/yr)	PERC USED (gal/yr)	APPROXIMATE MILEAGE (lbs/gal)	STATUS (as of 9/14/92) TESTING	ANALYSIS
(A)	Transfer w/Carbon Adsorber	30-lbs NA**	16,000	500	30	TBD*	TBD
(B)	Transfer w/Carbon Adsorber	35-lbs NA	60,000	<200	300	Complete	In progress
(C)	Transfer w/Refrigerated Condenser	70-lbs 6 yrs	210,000	1,300	160	Complete	In progress
(D)	Dry-to-Dry Vented w/Carbon Adsorber	30-lbs 9 yrs	60,000	300	200	TBD	TBD
(E)	Dry-to-Dry Vented w/Refrigerated Condenser	40-lbs 5 yrs	60,000	130	460	Complete	In progress
(F)	(2) Dry-to-Dry Vented w/Carbon Adsorber	190-lbs NA	940,000	3,600	260	Complete	In progress
(G)	Dry-to-Dry Non-Vented w/Refrigerated Condenser	35-lbs 6 yrs	50,000	100	500	TBD	TBD
(H)	(2) Dry-to-Dry Non-Vented w/Refrigerated Condenser	40-lbs NA	60,000	70	860	TBD	TBD
(I)	Dry-to-Dry Non-Vented w/Refrigerated Condenser and Carbon Adsorber	75-lbs 1 yr	NA	NA	NA	Complete	In progress
(J)	Conv. Dry-to-Dry Non-Vented w/Refrigerated Condenser	30-lbs 12 yrs	12,000	160	80	In progress	TBD
(K)	Conv. Dry-to-Dry Non-Vented w/Refrigerated Condenser	30-lbs >8 yrs	60,000	300	200	In progress	TBD

* TBD = To Be Done
** NA = Information Not Available

9/16/92

Preliminary Testing Results: Measured Concentrations of Perc

Facility	Machine Exhaust (ppm)	Room Vent (ppm)	Upwind Monitor (ppb)	Downwind Monitor (ppb)
(B)	830	3.5	2.4	26
(C)	7,600-9,700	3.6-34	0.77-10	8.9-140
(F)	5.7-9.4	12-31	3.1-3.2	124

9/92

Staff Presentation

- Background
- Preliminary Technical Evaluation
- Economic Analysis
- Regulatory Schedule
- Regulatory Concepts

Economic Impacts to be Evaluated

- Compliance costs for dry cleaners
- Other business impacts
- Impacts on small businesses
- Costs to districts and state agencies

Compliance Costs

Compliance Costs = any additional costs to a dry cleaner to comply with the requirements

- Capital and/or conversion costs for equipment
- Added operation and maintenance costs
- Added labor costs
- Added permit fees
- Added financing or other costs

Capital Costs for Selected Equipment

Equipment Type	Range of Costs (includes installation)
New Closed Loop with RC*	
~35 lbs capacity	$35-48k
~50 lbs capacity	$48-59k
~75 lbs capacity	$55-70k
Converted Closed Loop w/ RC*	$6-10k
Add-on refrigerated condenser	$8-16k
Add-on carbon adsorber	$6-10k

*RC=refrigerated condenser

9/92

Staff Presentation

- Background
- Preliminary Technical Evaluation
- Economic Analysis
- Regulatory Schedule
- Regulatory Concepts

Tentative Schedule For Future Meetings

- Third public meeting: January 1993
  - Draft regulation
  - Complete draft Technical Support Document (TSD)
- ARB hearing and possible adoption: May 1993
  - Proposed regulation
  - Staff Report
  - Revised TSD

Tentative Implementation Schedule

ARB adoption	May 1993
Administrative Review	Late 1993
Effective Date	Early 1994
District Adoption	Mid 1994*
Compliance	1994* or later as stated in regulation

*A district may act sooner

9/92

Staff Presentation

- Background
- Preliminary Technical Evaluation
- Economic Analysis
- Regulatory Schedule
- Regulatory Concepts

Design of the Regulation

State law requires us to design the regulation

"...to reduce emissions to the lowest level achievable through application of best available control technology..."

considering the potential risk, cost, and impacts.

9/92

Regulatory Concept Objectives

1. Establish good operating practices for all dry cleaners
2. Move cleaners into better equipment (if applicable)
3. Provide a quantitative standard to evaluate performance
4. Balance public health protection and costs

9/92

I. Good Operating Practices (for <u>ALL</u> facilities)

1. Operator training/certification
2. Education/compliance assistance
3. Operation, maintenance, and inspection requirements
4. Pollution prevention incentives
5. Recordkeeping and reporting

9/92

II. New Dry Cleaning Operations

A. Equipment:

Closed-loop machine w/refrigerated condenser; drying sensor; control device for machine door; overflow trough

B. Operation and Performance:

Ventilation/exhaust requirements; mileage/performance standard

C. Residential Locations:

Siting advisories to local agencies; additional containment/control of fugitive emissions

9/92

III. Existing Dry Cleaning Operations

A. Tiers:

Small, medium, and large, based on amount of clothes cleaned

B. Equipment, Operation, and Performance:

For SMALL, MEDIUM, and LARGE facilities: phase out transfer machines and replace with closed loop machines w/ refrigerated condenser

9/92

III. Existing Dry Cleaning Operations (cont.)

B. Equipment, Operation, and Performance (cont.):

1. SMALL facilities: control dry-to-dry vented machines
2. MEDIUM facilities: control OR phase out dry-to-dry vented machines; drying sensor; mileage/performance standard
3. LARGE facilities: phase out dry-to-dry vented machines; drying sensor; control device for machine door; ventilation/exhaust requirements; mileage/performance standard

9/92

III. Existing Dry Cleaning Operations (cont.)

C. Residential Locations:

Additional containment/control of fugitive emissions

D. Compliance Schedule OPTIONS:

- One date for all facilities
- Two dates based on status under EPA's standard
- Three dates based on facility size category
- Multiple dates based on facility Perc use
- Multiple dates based on facility Perc mileage

9/92

Select Bibliography of Materials Relating to Drycleaning

Alliance of Textile Care Associations. 1988. *Analysis of Dry Cleaning Variables on Perchloroethylene Residues.* Washington, DC. August.

Barnes, D.G. and M.L. Dourson. 1988. Reference Dose (RfD): Description and Use in Health Risk Assessment. *Reg. Toxicol. Pharmacol.* 8:471-486.

Barry Lawson Associates Inc. 1991. *Dry Cleaning Business.* New England Interstate Water Pollution Control Commission. Fall.

Brackemann, H. 1990. *Revised Version of the Second Federal Emissions Safety Regulation and Its Effect on the Operation of Dry Cleaning Plants.* Federal Office of the Environment, Berlin. Translated by SCITRAN, Santa Barbara, CA.

Brown, D.P., M.P.H., and S.D. Kaplan, M.D. 1987. *Retrospective Cohert Mortality Study of Dry Cleaner Workers Using Perchloroethylene.* June.

Brown, P. 1991. Dry-Clean Chemical Targeted, *Albany Times Union.* Monday, July 22, 1991.

Buben, J.A. and E.J. O'Flaherty. 1985. Delineation of the Role of Metabolism in the Hepatotoxicity of Trichloroethylene and Perchloroethylene: A Dose-Effect Study. *Toxicol. Appl. Pharmacol.* 78:105-122.

California Department of Health Services. 1991. *Proposed Identification of Perchloroethylene as an Air Contaminant.* Technical Support Document. August.

CARB, 1991. State of California Air Resources Board. *Proposed Identification of Perchloroethylene as a Toxic Air Contaminant.* Staff Report, August.

Carpenter, C.P. 1937. The Chronic Toxicity of Tetrachloroethylene. *J. Ind. Hyg. Toxicol.* 19:323-336.

CEC. 1992. Center for Emissions Control. *Dry Cleaning—An Assessment of Emission Control Options.* Final Draft, March.

Daft, J.L. 1988. Rapid Determination of Fumigant and Industrial Chemical Residues in Food. *J. Assoc. Off. Anal. Chem.* 71(4).

Derosa, C.T., M.L Dourson, and R. Osborne. 1989. Risk Assessment Initiatives for Noncancer Endpoints: Implications for Risk Characterization of Chemical Mixtures. *Toxicol. Ind. Health* 5:805-824.

Dmitrieva, N.V. 1968. Bioelectric Activity and Electric Conducting Properties of Muscles Exposed to Chlorinated Hydrocarbons. *Farmakologiya i Toksikologiya* 31(2):228-230.

Entz, R.C., K.W. Thomas, and G.W. Diachenko. 1982. Residues of Volatile Halocarbons in Foods Using Headspace Gas Chromatography. *J. Agric. Food Chem.* 30:846-849.

Entz, R.C. and G.W. Diachenko. 1988. Residues of Volatile Halocarbons in Margarines. *Food Additives and Contaminants* 5(3):267-276.

EPA, n.d. U.S. Environmental Protection Agency. *Investigation of Non-Occupational (Consumer) Exposure to Perchloroethylene from Dry-Cleaned Fabrics.* Washington, DC.

EPA. 1985. U.S. Environmental Protection Agency. Health Assessment Document for Tetrachloroethylene (perchloroethylene). EPA/600/8-82/005F. Office of Health and Environmental Assessment, ORD, Research Triangle Park, NC.

EPA. 1988a. U.S. Environmental Protection Agency. Reference Dose (RfD): Description and Use in Health Risk Assessments. Integrated Risk Information System (IRIS). On-line. Intra-Agency Reference Dose (RfD) Work Group, Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office. Cincinnati, OH.

EPA. 1988b. U.S. Environmental Protection Agency. Air and Energy Engineering Research Laboratory. *Evaluation of Perchloroethylene Emissions from Dry Cleaned Fabrics.* EPA/600/2-88/061. October.

EPA. 1988c. U.S. Environmental Protection Agency. *Evaluation of Perchloroethylene Emissions from Dry Cleaned Fabrics.* Air and Energy Engineering Research Laboratory. Research Triangle Park, NC. EPA/600/2-88/061. October.

EPA. 1989. U.S. Environmental Protection Agency. *Risk Assessment Guidance for Superfund. Vol. 1. Human Health Evaluation Manual (Part A).* EPA/540/1-89/002. OERR. Washington, D.C.

EPA. 1990a. U.S. Environmental Protection Agency. *Drycleaning and Laundry Plants.* EPA/530/SW-90/027b. Hazardous waste fact sheet.

EPA. 1990b. U.S. Environmental Protection Agency. *Dry Cleaning and Laundry Plants.* EPA/530/SW-90/027b.

EPA. 1991a. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *Economic Impact Analysis of Regulatory Controls in the Dry Cleaning Industry.* EPA/450/3-01/021. Final, October.

EPA. 1991b. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *Dry Cleaning Facilities—Background Information for Proposed Standards.* EPA/450/3-91/020a. Draft, November.

EPA. 1991c. U.S. Environmental Protection Agency, Region I Groundwater Management Section and U.S. Environmental Protection Agency Headquarters, Office of Ground Water and Drinking Water. *Preventing Pollution in the Drycleaning Business.* Brochure, Fall.

EPA. 1991d. U.S. Environmental Protection Agency. *Cleaning Industry.* Office of Air Quality Planning and Standards. Research Triangle Park, NC. October.

EPA. 1991e. U.S. Environmental Protection Agency. *Dry Cleaning Facilities Background Information for Proposed Standards.* Office of Air Quality Planning and Standards. Research Triangle Park, NC. November.

EPA. 1991f. U.S. Environmental Proetection Agency. Proposed Rules for Perchloroethylene. *Federal Register* 56(236). December.

French, M.T. and L.D. McNeilly. 1987. *Economic Impact Analysis for the Replacement of Transfer Dry Cleaning Machines with Dry-to-Dry Machines.* Center for Economics Research. Research Triangle Institute Park, NC. July.

Gove, J. 1992. *Summary of State Regulations on Perchloroethylene Dry Cleaners.* Memorandum from John Gove, Bureau of Air Management, Planning and Standards to members of the NESCAUM Air Toxics Committee. January 8.

Guo, Z., B.A. Tichenor, M.A. Mason, and C.M. Plunket. 1990. The Temperature Dependence of the Emission of Perchloroethylene from Dry Cleaned Fabrics. *Environmental Research* 52:107-115.

Haddad, A. 1991. State Seeks to Recoup Cost of Ground-water Cleanup: Officials Negotiate Over Contamination from Dry-Cleaner Business, *The Baltimore Sun.* Sunday, February 17, 1991.

Hake, C.L. and R.D. Stewart. 1977. Human Exposure to Tetrachloroethylene: Inhalation and Skin Contact. *Environ. Health Perspt.* 21:231-238.

Halogenated Solvents Industry Alliance, n.d. *The Safe Handling of Perchloroethylene Dry Cleaning Solvent.*

Heikes, D.L. 1987. Pesticide and Industrial Chemical Residues: Purge and Trap Method for Determination of Volatile Halocarbons and Carbon Disulfide in Table-Ready Foods. *J. Assoc. Off. Anal. Chem.* 70(2).

Hertzberg, R.C. and M. Miller. 1985. A Statistical Model for Species Extrapolation Using Categorical Response *Data. Toxicol. Ind. Health* 1(4):43-63.

Hertzberg, R.C. 1989. Extrapolation and Scaling of Animal Data to Humans: Fitting a Model to Categorical Response Data with Application to Species Extrapolation and Toxicity. *Health Physics* 57(Suppl. 1): 405-409.

HEW, n.d. U.S. Department of Health, Education and Welfare. *Tetrachloroethylene(Perchloroethylene).* National Institute of Safety and Health.

HEW. 1976. U.S. Department of Health, Education and Welfare. *Criteria for a Recommended Standard: Occupational Exposure to Tetrachloroethylene.* July.

International Fabricare Institute. 1975. *Experimental Study on Solvent Discharge from Dry Cleaning Establishments to the Environment.* Field Study of California Dry Cleaning Plants. International Fabricare Institute-Research Center. Silver Spring, MD. May.

Izzo, Victor J. 1992. *Dry Cleaners—A Major Source of PCE in Ground Water.* California Regional Water Quality Control Board, Central Valley Region. March.

Jensen, S.A. and C. Ingvordsen. 1977. *Tetrachloroethylene Content in Garments Which Have Been Cleaned in Coin-operated Dry Cleaning Machines.* Danish Institute of Technology. January.

Kjellstrand, P., B. Holmquist, M. Kanje, P. Alm, S. Romare, I. Jonsson, L. Mansoon, and M. Bjerkemo. 1984. Perchloroethylene: Effects on Body and Organ Weights and Plasma Butrylcholinesterase Activity in Mice. *Acta Pharmacol. Toxicol.* 54:414-424.

Klein, P. and J. Kurz. 1990. *Studies of Solvent-Retention Capacity of Textiles When Dry Cleaned.* SCI-TRAN. Santa Barbara, CA. November.

Kylin, B., H. Reichard, I. Sumegi, and S. Yllner. 1963. Hepatotoxicity of Inhaled Trichloroethylene, Tetrachloroethylene, and Chloroform—Single Exposure. *Acta Pharmacol. Toxicol.* 20:379-385.

Larsen, N.A., B. Nielsen, and A. Ravin-Nielsen, n.d. Perchloroethylene Intoxication—A Risk When Using Coin-Operated Dry Cleaning Machines. *Ugeskr. Laeg.*

Lauber, J.D., P.E., n.d. *Best Available Control Technology and Exposure Reduction for Dry Cleaning Operations.* New York State Department of Environmental Conservation.

Laundry & Cleaning News. 1991. Environmental Costs Balance Out Well, *Laundry & Cleaning News International*. March 8, 1991, 13(4):34.

Levelton, B.H. & Associates. 1991a. *Environmental Code of Practice for the Reduction of Solvent Emissions from Dry Cleaning Facilities*. Prepared for Environment Canada, Industrial Programs Branch. Draft, December.

Levelton, B.H. & Associates. 1991b. *Background Information for an Environmental Code of Practice for Dry Cleaning Facilities*. Prepared for Environment Canada, Industrial Programs Branch. Draft, December.

McGrath, S. 1992. One of Seattle's Perks: A Dry Cleaner with Minimal Perc, *Seattle Times*. Sunday, January 26.

Metropolitan Water District of Southern California and the Environmental Defense Fund. 1990. *Source Reduction of Chlorinated Solvents*. June.

Miller, L.J. and A.D. Uhler. 1988. Volatile Halocarbons in Butter: Elevated Tetrachloroethylene Levels in Samples Obtained in Close Proximity to Dry-Cleaning Establishments. *Bull. Environ. Contam. Toxicol.* 41:469-474.

Morgan, R. 1991a. Consumer Problems with the Dry Cleaning of Textiles. *Australian Textiles*. March.

Morgan, C. 1991b. Dry Cleaners Working to Tidy Up Their Image. *Miami Herald*. Monday, December 2.

Morgan, C. 1991c. Dry Cleaners' Dirty Legacy: Pollution in Drinking Water. *Miami Herald*. Monday, December 2.

Myers, R.H. 1986. *Classical and Modern Regression with Applications*. Boston: Duxbury Press.

National Analysis. 1987. *Attitudes and Problems in Compliance with VOC Regulations*. April.

Navrotskii, V.K., I.L. Kashin, L.F. Kulinskaya, L.M. Mikhaylovskaya, Z. Shuster, N. Burlaka-Vouk, and B.V. Zadarozhniy. 1971. Comparative Assessment of the Toxicity of a Number of Industrial Poisons When Inhaled in Low Concentrations for Prolonged Periods. *Trudy S'ezda Gigen Vkramkoi* SSS 8:224-226.

NCI. 1977. National Cancer Institute. *Bioassay of Tetrachloroethylene for Possible Carcinogenicity*. DHEW Pub. No. (NIH) 77-813. U.S. Department of Health, Education, and Welfare, Public Health Services. National Institutes of Health, Bethesda, MD.

NESCAUM. 1992. Northeast States for Coordinated Air Use Management. Proceedings for Workshop on Emission Control Strategies for Dry Cleaners. January 8. Boston.

NTP. 1986. National Toxicology Program. *Toxicology and Carcinogenesis Studies of Tetrachloroethylene in F344/N Rats and Female B6C3F1 Mice (Inhalation Studies)*. Tech. Report Series No. 311. U.S. Health and Human Services, National Institutes of Health, Bethesda, MD.

NYSDH. 1991a. New York State Department of Health. *Status Report on Use and Replaceability of Tetrachloroethylene (PERC) in the Federal Republic of Germany*. Translated by SCITRAN, Santa Barbara, CA.

NYSDH. 1991b. New York State Department of Health. Tetrachloroethylene Pollution of Residents Adjacent to Dry Cleaners. Translated from *Off Gesundh-Wes.*, 1989. Translated by Rockland Technical Services, New York, NY.

NYSDH. 1991c. New York State Department of Health. Contamination of Foodstuffs by Emissions from Dry Cleaning Establishments. Translated from *Z Lebensm Unters Forsch*, 1988. Translated by Rockland Technical Services, New York, NY.

NYSDH. 1991d. New York State Department of Health. Investigations of the Presence of Tetrachloroethylene in Indoor Air and Food in Dwellings in the Vicinity of Dry Cleaning Shops. Translated from *Zbl. Hgy.*, 1989. Translated by Rockland Technical Services, New York, NY.

NYSDH. 1991e. New York State Department of Health. Tetrachloroethylene Exposure in the Neighborhood of Dry Cleaners. Translated from *Off Gesundh-Wes.*, 1989. Translated by Rockland Technical Services, New York, NY.

NYSDH. 1991f. New York State Department of Health. Bureau of Toxic Substance Assessment. *Investigation of Indoor Air Contamination in Residences above Dry Cleaners*. Albany, NY. October.

Ontario Ministry of the Environment. 1990a. *Hazardous Waste Management Practices of the Ontario Dry Cleaning Industry*. December.

Ontario Ministry of the Environment. 1990b. *An Economic Study on Improved Management of Dry Cleaning Industry Wastes*. December.

Pfeiffer, M.B. 1992. Cleaned Out: The State is Finally Moving Against Dry Cleaners for Air Pollution—But It May Be Too Little Too Late, *Village Voice*. January 14.

Rao, V.R. 1992. *Noncancer Health Risks for Residents Located in the Vicinity of Drycleaners*. Report submitted to OPAR (EPA) and AAAS, August.

Reinhard, K., W. Dulson, and M. Exner, n.d. *Investigations on Concentrations of Tetrachloroethylene in Indoor Air and Food in Residences in the Vicinity of Dry Cleaning Shops.* Institute for Environmental Research of the Office for Environmental Protection of the City of Cologne.

Rosengren, L.E., P. Kjellstrand, and K.G. Haglid. 1986. Tetrachloroethylene: Levels of DNA and S-100 in the Gerbil CNS after Chronic Exposure. *Neurobehavioral Toxicol. and Teratol.* 8:201-206.

Rowe, V.K, D.D. McCollister, H.C. Spencer, E.M. Adams, and D.D. Irish. 1952. Vapor Toxicity of Tetrachloroethylene for Laboratory Animals and Human Subjects. *Arch. Ind. Hyg. Occup. Med.* 5:566-579.

Schreiber, J. 1992. New York State Department of Health. *Tetrachloroethene Health Effects.* Abstract Booklet for International Roundtable on Pollution Prevention and Control in the Drycleaning Industry. U.S. EPA/OPPT. May 27-28.

Seeber, A. 1989. Neurobehavioral Toxicity of Long-Term Exposure to Tetrachloroethylene. *Neurotoxicol. Teratol.* 11:579-583.

SRRP, 1990. Source Reduction Research Partnership (Metropolitan Water District of Southern California/Environmental Defense Fund). *Source Reduction of Chlorinated Solvents—Dry Cleaning of Fabrics.* Final Draft, June.

Stewart, R.D., E.D. Baretta, H.C. Dodd, and T.R. Torkelson. 1970. Experimental Human Exposure to Tetrachloroethylene. *Arch. Environ. Health* 20:224-229.

Stewart, R.D., C.L. Hake, A. WU, J. Kaldfleisch, P.E. Newton, S.K Marloro, and M.V. Salama. 1977. *Effects of Perchloroethylene/Drug Interaction on Behavior and Neurological Function.* Final Report, National Institute for Occupational Safety and Health, April.

TRI/Princeton. 1989. *Development of Analytical Procedure for Perchloroethylene Residues in Textiles.* Princeton, NJ. January.

Tsuruki, K. and N. Keitaro. 1989. Residual Tetrachloroethylene in Dry-Cleaned Clothes. *Environmental Research* 48:296-301.

Turk, R. 1991. Living Green and Refusing to Dry-Clean. *Los Angeles Times.* Saturday, March 9.

Tuttle, T., C.D. Wood, C.B. Grether, B.L. Johnson, and C. Xintaras. 1977. A Behavioral and Neurological Evaluation of Dry Cleaners Exposed to Perchloroethylene. Department of Health Education and Welfare (NIOSH). Pub. No.77-214. Washington, DC.

United Nations Environment Programme. 1989. *Technical Progress on Protecting the Ozone Layer.* Electronics, Degreasing and Dry Cleaning Solvents Technical Options Report. June.

Van den Berg, J.H. and W.A.J.L. den Otter. 1989. *Test: Böwe P 540 Steam-heated with CONSORBA.* Prepared for Böwe Reinigungstechnik GmbH by Instituut voor Reinigungstechnieken TNO. Report, December