DRY CLEANERS WORKERS EXPOSED TO PERCHLOROETHYLENE

A Retrospective Cohort Mortality Study

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Menlo Park, California 94025

Contract Number 210-77-0094

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Cancer mortality rates among 1,597 persons employed in dry cleaning establishments and exposed to perchloroethylene (127184) (PCE) were studied. The cohort was selected from union records and vital status was determined through federal and local records. Of the 1,597 cohort members 1,058 were alive, 285 were dead and 254 had unknown vital status. Eleven deaths due to cancer of the colon were observed. Excess death rates also occurred for cancers of the pancreas and urinary tract, and hematologic diseases. The author recommends that this cohort be reevaluated again after several years in order to establish the relationship between PCE exposure and cancer of the colon.

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ABSTRACT

This investigation was undertaken as a result of animal experiments that indicated that perchloroethylene was a carcinogen in B6C3F1 mice. The study cohort consisted of 1,597 individuals who were employed for at least 1 year before 1960 in dry cleaning shops where the primary solvent was perchloroethylene and who had no previous occupational exposure to carbon tetrachloride or trichloroethylene. Eligible study cohort members were identified from the records of the following unions: the Oakland local of the AFL-CIO Laundry and Dry Cleaning International; the Chicago local of the Laundry, Dry Cleaning, and Dyehouse Workers International Union; and the Detroit and New York City locals of the Amalgamated Clothing and Textile Workers Union. These records were supplemented by solvent history information on union local member shops obtained from a variety of sources. Those shops for which solvent histories could not be obtained were assumed to have used petroleum solvents (as did the majority of shops before 1960 for which the solvent history was known).

Follow-up was carried out through the Social Security Administration, state drivers's license and motor vehicle registration authorities, the Internal Revenue Service, and the Postal Service. Death certificates were obtained from the Vital Statistics offices of the states where death occurred and were coded for cause of death by a nosologist under contract to NIOSH. Work history, demographic data, and cause of death information were coded, keypunched, and edited at SRI in a standard manner and were analyzed by the use of NIOSH's modified life table program.

Of the 1,597 eligible study cohort members, 1,058 were alive at the common closing date (September 30, 1977), 285 were known dead, and 254 were of unknown vital status. Death certificates were obtained for 247 of the 285 deceased study cohort members. Race was known only for deceased study cohort members from death certificates; based on that information, between 20 and 50% of the study cohort in each union local was black, and virtually all the remainder of the study cohort members were white. Because of this uncertainty about ethnicity, the results are presented separately for expected numbers of deaths based on death rates for whites and for blacks. When available, a point estimate of the SMR is presented based on the person-years distribution by age for whites and nonwhites (known only for the deceased whose race was recorded on the death certificate). The person-years of those lost to follow-up were truncated at the time they were last known to be alive. The SMRs (standard mortality ratios) were corrected under the assumption that when death certificates were not obtainable, these deaths were distributed by cause similarly to those by known cause.

We conclude that the study cohort members are at very low risk of death from accidents, with no deaths reported from motor vehicle accidents. Conclusions about increased risk of death from other causes are limited by the relatively small numbers in the cohort and by the necessity of invoking the different assumptions. Based on the study results, cancer of the colon, which accounted for 11 observed deaths, appears to be the cause of death most likely to have resulted from occupational exposure in our cohort.

We recommend that the study cohort be reexamined for vital status and cause of death several years hence to increase the probability of either establishing or excluding this conclusion. At the same time, particular attention would be paid to other causes of death where conclusions were limited either by small numbers of observed deaths or different results for white and black rates or both. These additional causes include: cancer of the rectum, cancer of the pancreas, cancer of the urinary tract, other and unspecified cancers, cancers of the respiratory system, diseases of the blood and blood-forming organs, and diseases of the genitourinary system.

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INTRODUCTION

Although as recently as 1972 it could be written that "There is plenty of evidence that no simple chlorinated hydrocarbon, however toxic, has ever been known to cause tumours in man" (Munn, 1972), today we know better. Studies by NIOSH and other investigators have shown that vinyl chloride is a human carcinogen (National Cancer Institute, 1978), and the close chemical relationship of perchloroethylene to vinyl chloride arouses concern about possible carcinogenic effects of perchloroethylene in humans.

For this reason, bioassays were conducted of USP Grade tetrachloroethylene in corn oil administered by gavage in either of two doses to groups of 50 male and 50 female Osborne-Mendel rats and B6C3F1 mice. Among the rats, no significant increase in incidence of neoplastic lesions was observed, although a high proportion of the treated rats developed toxic nephropathy. In mice, there was a significantly increased incidence of hepatocellular carcinoma. These cancers were observed in 2 of 17 untreated control males and in 2 of 20 untreated control females, in 2 of 20 vehicle (corn oil) control males and 0 of 20 vehicle control females, in 32 of 49 males and 19 of 48 females treated with the low dose, and in 27 of 48 males and 19 of 48 females treated with the high dose (National Cancer Institute, 1977).

One workplace in which perchloroethylene has been used extensively is the dry cleaning industry. Perchloroethylene was introduced in the late 1930s and, according to trade associations and equipment manufacturers, replaced carbon tetrachloride as a solvent in that industry shortly after World War II. However, during that period, petroleum solvents were still the predominant solvents used in dry cleaning. A gradual shift from petroleum derivatives to perchloroethylene began in the late 1940s and picked up momentum in the 1950s and early 1960s. By 1977, the industry estimated that approximately 74% of commercial dry cleaning plants used perchloroethylene, about 24% used petroleum solvents, and the remainder used fluorocarbons. However, in the period before 1960, petroleum derivatives were still the dominant solvents.

In view of the close chemical relationship of perchloroethylene to a known human carcinogen, the recent evidence of carcinogenesis of perchloroethylene in animals, and the long-term widespread exposures of workers in the dry cleaning industry to this chemical, the retrospective cohort mortality study described in this report was planned.

DEFINITION AND IDENTIFICATION OF THE STUDY COHORT

DEFINITION

The contract specified that the study cohort comprise a minimum of 1,500 individuals (to minimize any small number effects) exposed to perchloroethylene for at least 1 year (to allow a long enough duration of exposure for any effects to occur) before 1960 (to allow for the elapse of the latent period for any effects) with no previous occupational exposure to carbon tetrachloride or trichloroethylene (so that any effects found could not be attributed to these two chemicals).

In practice the identification of this study cohort proved so difficult as to be virtually impossible. This was an unexpected development because the number of potential sources of data was large and the sources were varied.

POTENTIAL DATA SOURCES

Direct Identification of Individuals

The first possible approach SRI considered was to identify directly individuals exposed to perchloroethylene by taking advantage of the practice of the State of California of licensing owners of dry cleaning establishments as well as the establishments themselves. Because a licensed operator is required to be present in each dry cleaning establishment, this meant that one employee of each establishment could be identified as working in that establishment. The licensing information for the establishment includes the solvent that is used, and the list of operators gives the name of the establishment and the operator's name and social security number.

Licenses must be renewed annually, but unfortunately those that are not renewed because the operator has died, retired, changed occupations, or moved out of state are destroyed after 5 years. Use of this source would obviously have resulted in a severe bias; for example we would not have been able to identify licensees who had died more than 5 years earlier.

Dry Cleaning Establishments

This led to the second approach of trying to identify dry cleaning establishments where perchloroethylene was used before 1960 to determine whether they had records of employees who were exposed to perchloroethylene at that time.

SRI investigators approached the following potential sources, but they were unable to provide any information on plants:

- State chambers of commerce
- State listing by SIC codes
- National trade associations.

Other sources of lists of dry cleaning establishments were able and willing to cooperate with SRI. By December 1977, SRI had obtained lists of dry cleaning establishments from 12 regional, state, and local trade associations, 5 governmental licensing authorities, and 2 manufacturers of dry cleaning equipment. From some of these lists, we were also able to identify either establishments that opened before 1960 or establishments that were known to use perchloroethylene.

SRI's research assistants contacted dry cleaning establishments on the lists during October and November 1977 to determine the solvent history of plants, particularly whether perchloroethylene was used before 1960 and whether carbon tetrachloride or trichloroethylene had ever been used as a solvent. The person contacted at those establishments that were identified as users of perchloroethylene before 1960 was asked about record retention policies. Specifically, that person was asked whether records existed that could identify by name, social security number, date of birth, date of employment, and job title individuals employed at these plants for more than a year before 1960 during the dates when perchloroethylene was used. If the contacts stated that such records were available, they were asked if having the records copied would be permissible at some later date, if the project officer selected the plant for inclusion in the study. At those establishments that gave permission, the contact was asked for an approximate number of individuals in the plant who would have qualified for the study cohort.

SRI sent to the project officer in November 1977 lists of those plants that qualified for the study by solvent history and claimed record retention policies. These lists included name and address of the plant, the name of the contact, and the number of records (although in many cases we were given a point prevalence count of number of employees, which underestimated the total eligibles because turnover was not considered). The number of estimated eligible available records eventually reached more than 2,000, and the project officer began to select specific dry cleaning establishments for inclusion in the study cohort.

Once the project officer had selected specific establishments for inclusion, SRI's research assistants called these establishments in December 1977 to determine a schedule for copying their records. At this point, with only one or two exceptions, the owners notified us that they had no records containing the information we needed. These dismaying tidings were surprising because in previous telephone conversations and responses to letters, these owners had assured us that they had these records and that the records contained the information required.

Ohio State Prison

Fortunately, concurrent efforts had been carried out to identify other sources of records besides the dry cleaning establishments themselves. For example, SRI discovered during November 1977 that the Ohio State Prison had

been using perchloroethylene as a dry cleaning solvent for many years. Unfortunately, however, many of the records that could have identified inmates and guards who worked in the prison dry cleaning plant and were exposed to perchloroethylene were completely destroyed in a fire at the prison, and the remainder of the records were partly destroyed so that we could not identify the specific dates of exposure.

U.S. Navy

Another potential source of records SRI found during November 1977 was the U.S. Navy. Perchloroethylene had been used as the only dry cleaning solvent in the Navy exchanges since World War II. The Navy computerized records of employees of these Navy exchanges as far back as 1960. Unfortunately for purposes of the study, when the computerized system was installed, the Navy destroyed all its pre-1960 records—including records of employment. Therefore, there is no way to identify employees who worked before 1960 (except for the ones who were included because they worked in 1960 and later).

Unions

The only source of records of dry cleaners workers that has not yet been mentioned in this report is records of unions of dry cleaners workers. To be useful for this study, these records had to include the name, date of birth, and social security number of the union member and the name of the dry cleaning establishment where he or she was employed before 1960; these records had to be available also for those who had subsequently died, retired from the union, or quit the union.

SRI searched between November 1977 and March 1978 and found only five large union locals in the entire United States that fulfilled these conditions: the Oakland local of the AFL-CIO Laundry and Dry Cleaning International; the Chicago and St. Louis locals of the Laundry, Dry Cleaning, and Dyehouse Workers' International Union; and the Detroit and New York City locals of the Amalgamated Clothing and Textile Workers Union. The St. Louis local records were already being used as the data source for a retrospective cohort mortality study of the entire dry cleaning industry by the National Cancer Institute. That union local was therefore not used as a data source in order to keep the two studies completely independent.

DATA COLLECTION

UNION RECORDS

SRI's research assistants visited the Oakland, Detroit, Chicago, and New York union locals between December 1977 and June 1978 and microfilmed the records for all union members working in dry cleaning establishments before 1960. Information obtained from the microfilmed records included name, date of birth, social security number, and date and place of employment. Information on job history varied with the union locals. Only the Oakland local had a complete job history for all members. At the other extreme, the Detroit local had no job history information.

Union records therefore provided direct information about time worked but not about solvent exposure. In fact, none of the unions had a complete list of all present and past member dry cleaning shops. Therefore, our first step to determine eligibility was to compile a master list of all past and present union member shops by name and address from the microfilmed union records. (The address was important for two situations—namely, when a change in ownership of a dry cleaning establishment also resulted in a change of name of the establishment, and when several establishments with very similar names had employees who belonged to the same union local.)

To determine whether a particular union member qualified for the study, we needed to obtain the solvent history of the establishments in which he or she worked. Some of the establishments already had known solvent histories, either because SRI investigators had contacted them at the time when it was thought that the records of the dry cleaning shops could be copied directly or because they were listed as purchasers of dry cleaning equipment using perchloroethylene before 1960 by two cooperating equipment manufacturers (Detrex Chemical Industry, Inc., of Detroit and Vic Manufacturing Company of Minneapolis) that provided this information to SRI during October and November 1977. In addition to this information, SRI's research assistants also obtained solvent history information beginning in January 1978 from readily available sources including:

- Present owners of dry cleaning shops (particularly for the Oakland union local)
- Union officials
- Local distributors of dry cleaning equipment (particularly for the Chicago union local)
- Local distributors of perchloroethylene (particularly for the Detroit union local).

The City of Chicago had complete solvent history records on all member shops of the Chicago local, but many of these records were illegible because of water and rodent damage.

This procedure proved insufficient. By May 1978, when we had completed the procedure for the Oakland, Detroit, and Chicago union locals, it was clear that fewer than 800 union members were known to qualify for the study cohort. At the request of the project officer, additional funds were supplied so that we could contact sources of solvent history information in all four locations between June and October 1978. In addition to the types of sources already described, the following data sources were also approached by SRI investigators:

- Heads of trade associations covering these areas
- Licensing authorities
- Former owners
- Other individuals with a long knowledge of the local dry cleaning industry.

For the Oakland, Detroit, and Chicago union locals, more than 100 additional perchloroethylene-using establishments were identified.

INSURANCE COMPANY FILES

After we had identified members of the New York union who qualified for the study on the grounds of solvent history (as described in the section "Classification of Exposure"), many of them were found to lack date of birth information. The insurance carrier for the New York City union local had date of birth information for virtually all the past and present members of the local, so in November 1978 SRI research assistants obtained this missing information from the insurance company records in most cases for the local members who otherwise qualified but lacked date of birth information.

INDUSTRIAL HYGIENE STUDY

In combination with this study, NIOSH conducted an industrial hygiene survey at dry cleaning facilities currently using perchloroethylene. Many of the facilities visited were in the study cohort, but because they represented shops that have remained open for at least 20 years, great caution should be exercised in generalizing the findings from these shops to all facilities that contributed eligible study cohort members.

The design and results of this survey are described in detail elsewhere. However, points from the survey that are relevant to this report are as follows.

The levels of perchloroethylene are much higher for the cleaners (i.e., the machine operators) than for other employees in the shops. The geometric mean for perchloroethylene time-weighted averages was 22 ppm for the machine operators, with 95% confidence limits of 17 and 28. For all other jobs, the highest corresponding value was 3.3 ppm, and the highest 95% upper confidence limit was 6.8. In many of these shops, the machine operator was found to be the owner of the shop, and not all the owners are union members. In the larger shops, however, the owner tended to be more of a manager than an active production employee, and the majority of eligible study cohort members from the Detroit, New York, and Chicago union locals worked in a relatively small number of large shops of this type. Therefore, it is probable that most of the machine operators in these shops are in the study cohort, but it is also probable that the majority of the study cohort are not machine operators and therefore have relatively low exposures to perchloroethylene. Unfortunately, many of the machine shop operators in the study cohort cannot be identified because of the lack of job information on many study cohort members, including all the study cohort members of the Detroit union local.

The owners and employees interviewed during the industrial hygiene survey by NIOSH stated, as a general impression, that exposures to perchloroethylene were not dramatically higher in that shop 20 years earlier than they were at the time of the survey. This impression was based on the similarity of equipment and process techniques used at the two time points.

CLASSIFICATION OF EXPOSURE

Even after all cooperating sources of solvent histories were exhausted, the solvent history of the majority of member shops was unknown. Many of the shops had closed. Many others had changed ownership after 1960, and although the new owners knew the equipment that was in place when they bought the shops and hence knew the solvent used immediately before purchase of the shop, the new owners had no idea of how long that solvent had been used. In virtually every case, whether the shop had closed or whether the ownership had changed hands before 1960, the owner before 1960 could not be contacted. In most such situations, the cooperating sources of solvent history were not able to identify the solvent history of the shops.

However, the solvent history of nearly half the member shops was known from one or more sources. None of these shops were identified by SRI as using trichloroethylene as a solvent. Fewer than 20 used carbon tetrachloride at any time. As was true in general for the industry, carbon tetrachloride use virtually ceased after World War II, although one plant had a history of using it well into the 1950s until it switched to perchloroethylene. Of the remaining dry cleaning establishments with a known solvent history, many more used petroleum solvents than used perchloroethylene before 1960. Fewer than 10 switched from perchloroethylene to petroleum while dozens changed from petroleum to perchloroethylene before 1960.

Based on this information, SRI's project leader, with the approval of the project officer, decided to consider employment in a shop with unknown solvent history before 1960 as involving exposure to petroleum solvents. While this was the situation most likely to represent reality for a particular shop as determined from the solvent history of the other plants, it also, in some respects, represented the most conservative treatment. Time spent in a shop of unknown solvent history did not disqualify an individual otherwise qualified for inclusion in the cohort, whereas time spent in a carbon tetrachloride-using shop did. On the other hand, time spent in a shop of unknown solvent history did not qualify an individual who otherwise did not meet the criteria for inclusion in the study cohort and did not add to the estimate of duration of exposure to perchloroethylene.

Therefore, as specified in the contract, every individual in the study cohort had at least 1 year of exposure to perchloroethylene as a solvent before 1960, but the duration of exposure to perchloroethylene of some individuals has been underestimated. Because a few plants used carbon tetrachloride, it is possible that a relative handful of study cohort individuals may have been exposed to carbon tetrachloride. However, the proportion of plants with known solvent histories to plants with a history of carbon tetrachloride use is extremely small; and for those plants, the duration of carbon tetrachloride use was virtually always less than 5 years and in most cases

was much shorter. Therefore, it seems reasonable to assume that the number of study cohort members with carbon tetrachloride exposure is small enough to have no influence on the results.

CODING

The complete work history of every member of the study cohort was coded by SRI's research assistants between November 1978 and January 1979. Each union was given a code, and within each union each perchloroethylene-using plant was given a unique plant code. A unique code was set up to indicate work in plants that used petroleum solvents or were presumed to do so because the solvent history was unknown. For unions such as Oakland where job history information was available, the research assistants recorded the date of change from one job category to another cleaner, spotter or spotter cleaner, presser, counter worker, driver, laundry worker (in a plant where both laundry and dry cleaning are processed in the same room), other . For each change of job or change of plant (from one perchloroethylene-using plant to another or from a non-perchloroethylene-using plant to a perchloroethylene-using plant or vice versa), the starting and ending dates were recorded by month, day, and year at the request of NIOSH. When this information was recorded only for month and year, the day was listed as the fifteenth of the month as a default option.

The coded work history was entered on a face sheet attached to an envelope in which the hard copy of the original work history for the individual was placed. If a death certificate was available, it was placed in the envelope and the coded cause of death was entered on the face sheet. Cause of death was coded by NIOSH's nosologist according to the revision of the International Classification of Diseases and Causes of Death that was in force at the time of death. Date of birth and social security number were also coded for each individual. Union, plant, and job identification numbers were also coded, as was a unique 4-digit study number sequentially within each union. Those persons whose vital status was unknown were so identified on the face sheet. The same information was coded independently by a different coder and recorded on a different face sheet not including the envelope.

For the New York, Detroit, and Chicago union locals, the information on each of the two face sheets was keypunched independently at SRI during January and February 1979, and the two independent keypunch records were run against each other for verification. Any disagreements between the two coders and/or keypunchers were noted, resolved on the basis of the information in the records within the envelope by SRI's research assistants between January and March 1979, and corrected. For Oakland, because there were many jobs and shop changes, the procedure was deemed impractical. The doubly independent coded face sheets were compared by hand and corrected by SRI's research assistants. The information from the corrected Oakland face sheets was then keypunched and verified at SRI in the standard manner.

FOLLOW-UP

Only the Detroit and Oakland union locals had active members who were eligible for the cohort. Oakland also had some death certificates for deceased cohort members.

NIOSH submitted the names and social security numbers of all those whose vital status was unknown to the Social Security Administration (SSA) for tracing in two batches in June and December 1978. SRI listed by union the names of those whom the SSA could not find and returned the lists to the unions in November 1979 with a request for vital status information from business agents. SRI's research assistants also sent lists to state drivers' license and motor vehicle registration authorities beginning in July 1979 for vital status information. For each person identified by these authorities as being alive at a date earlier than the closing date of the study (September 30, 1977, the latest date for which the SSA had vital status information), SRI sent a card to the post office in December 1979, giving the name and last known address and requesting vital status.

NIOSH traced vital status through the Internal Revenue Service in January 1980 because it was not clear whether SRI, even as a government contractor bound by the Federal Privacy Act, had a legal right to carry out this follow-up. The IRS follow-up was supplemented by follow-up by NIOSH through the post office in March and April 1980.

Between March and July 1979, we requested death certificates from the Vital Statistics Office of the states in which death was alleged to have occurred. In New York, the certificates were requested both from the New York City and the New York State Vital Statistics offices. When there was no record of death in the state given, we queried other states. In all cases in which death certificates could not be found, at least two states were queried.

ANALYSIS AND DESCRIPTIVE STATISTICS

The total eligible cohort consisted of 1,597 individuals, of whom 571 were males and 1,026 were females. Of the study cohort members, 1,058 were alive, 285 were dead, and 254 were of unknown vital status. Table 1 shows the distribution of vital status for both males and females. As might be expected, the proportion with unknown vital status was much higher among females, who are more difficult to follow because of last name changes and because they are less likely to be ascertained by sources such as the SSA and the Internal Revenue Service.

Table 1. Vital status by sex of dry cleaners exposed to perchloroethylene.

	Alive		Dead		Unknown		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent by sex
Males	363	63.5	163	28.5	45	7.9	571	35.8
Females	695	67.7	122	11.9	209	20.4	1,022	64.5
Total	1,058	66.2	285	17.8	254	15.9	1,597	

Table 2 shows the vital status and follow-up rate by union separately for males and females. The follow-up rate was much better for the Oakland union, probably because that union was the only one able to give follow-up information on vital status of inactive union members. Follow-up was also considerably better for males in the New York union for reasons that are not clear. With the exception of Oakland, the follow-up rate for each union was much worse for the females. The other noteworthy point is the smaller proportion of deceased New York union members in the cohort as compared with the other three union locals. This is likely to be explained to a large extent by the fact that the New York union members in the cohort tended to be younger and a higher proportion was female than in the other three union locals.

Because of the relatively high proportion of individuals of unknown vital status, the analysis accumulates person-years for those individuals only until they are lost to follow-up. Table 3 shows the corresponding person-years distribution under this assumption.

Table 2. Vital status by sex and union local of dry cleaners exposed to perchloroethylene.

Union local	Vital Status: Number alive	Vital Status: Number dead	Vital Status: Unknown Number	Vital Status: Unknown Percent	Total Number	Total Percent by sex
Oakland						
Males	39	14	1	1.9	54	42.9
Females	62	9	1	1.4	72	57.1
Total	101	23	2	1.6	126	
Detroit						
Males	131	81	26	10.9	238	38.3
Females	263	49	72	18.8	384	61.7
Total	394	130	98	15.8	622	
Chicago						
Males	58	32	10	10.0	100	37.3
Females	109	21	38	22.6	168	61.7
Total	167	53	48	17.9	268	
New York						
Males	135	36	8	4.5	179	30.8
Females	261	43	98	24.3	402	69.2
Total	396	79	106	18.2	581	

Each individual in the study cohort came under observation (that is, was counted as contributing person-years of risk) only after he or she had been employed 1 entire year in dry cleaning shops that were known to use perchloroethylene as a solvent during that time of employment.

Observed deaths by cause were compared with those expected from the similar U.S. population separately by sex using the modified life table program of NIOSH. This program calculates rates separately for whites and blacks, but in the cohort race was known only for deceased individuals from the death certificate. If the racial distribution from the deceased cohort members can

Table 3. Person-years by age and time interval in dry cleaners exposed to perchloroethylene (individuals lost to follow-up assumed lost).

	Years								
Ages	1920-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total*
15-19	0.0	9.0	17.1	21.8	8.6	0.0	0.0	0.0	56.4
20-24	0.3	31.8	106.3	148.0	144.9	8.5	0.0	0.0	440.0
25-29	12.6	45.6	173.4	402.5	310.7	133.4	8.6	0.0	1,086.8
30-34	37.4	67.2	270.1	714.6	666.5	276.6	131.2	8.5	2,172.1
35-39	35.1	103.7	309.9	854.2	1,086.9	631.1	260.6	91.7	3,373.1
40-44	47.8	98.9	328.1	852.6	1,216.6	1,027.1	618.3	146.4	4,335.9
45-49	36.5	85.1	253.8	787.6	1,085.1	1,141.7	971.5	456.0	4,766.8
50-54	20.5	46.4	241.5	532.8	990.8	1,014.8	1,082.6	526.6	4,458.9
55-59	4.5	33.0	123.3	429.4	624.6	909.5	960.9	564.3	3,649.5
60-64	0.0	16.5	59.5	221.1	462.0	580.6	844.3	470.0	2,654.1
65-69	0.0	0.5	29.6	106.5	224.9	391.0	508.1	403.9	1,664.7
70-74	0.0	0.0	2.4	36.9	101.8	176.4	295.8	220.8	834.0
75-59	0.0	0.0	0.0	9.8	32.3	78.7	132.2	119.8	372.8
80-84	0.0	0.0	0.0	0.0	6.9	19.1	39.1	38.2	103.4
85+	0.0	0.0	0.0	0.0	0.0	3.3	8.2	6.8	18.3
Total*	194.0	537.7	1,915.0	5,117.8	6,962.6	6,391.8	5,861.4	3,005.7	29,986.8

*Some totals are off by one-tenth because of rounding.

be taken as representative of the racial distribution of the entire cohort, approximately 30% of the cohort was black, and virtually all the remainder of the cohort was composed of whites. Within each union, at least 20% of the deceased membership was black, but more than half of the deceased membership was white. Because there was no way to identify the race of living members of the cohort, the entire cohort was compared to mortality rates for both whites and blacks separately by sex.

Death certificates were obtained for all but 38 of the 285 cohort members known to be deceased. However, this percentage (13.3%) is high enough that, in calculating the SMRs for specific causes, those deaths for which no certificates were found were assumed to have the same distribution by cause as those for which death certificates were available. Those who died after the closing date of September 30, 1977, were treated as alive in the analysis.

Table 4 summarizes the mortality experience for the cohort for both black and white rates. For some causes of death, the magnitude of the SMR estimates is strongly affected by which of the rates is used. Because of these limitations, we devised a procedure to calculate more accurate point estimates of the SMRs. For those whose race was recorded--i.e., the deceased--the person-year distribution by age was calculated separately for whites and for nonwhites (virtually all of whom were black). For each 5-year age group, the ratio of known white person-years to known nonwhite person-years was assumed to be the same for all person-years accumulated within that age group category. Therefore, rates for whites were used for the proportion of the person-years in each age group that were whites, and rates for blacks were used for the remaining person-years to give a new expected number; that number was used to generate point estimates of the SMR. Even though this is perhaps a best estimate, there is much uncertainty in the assumptions; hence, the SMRs based on white rates and on black rates are also given in Table 4. Because of this uncertainty, the emphasis in the discussion of specific causes of death is on those that consistently show an increased SMR regardless of which rate is used.

In general, the number of cohort members in each union is too small for analysis, and therefore the results of SMRs by union are not presented in tables. However, when indicated, findings for specific unions are presented for certain causes of death.

According to the point estimate of the overall SMR, this cohort shows the healthy worker effect. However, more important than the all causes SMR is the SMR for specific causes of death and the number of deaths on which each of these SMRs is based.

Examination of the SMR magnitude for specific causes and the number of observed deaths on which the SMRs are based reveals a pattern for malignant neoplasms of the intestine except the rectum. All 11 deaths were actually from cancer of the colon, and of course virtually all the expected numbers of deaths from this cause were from cancer of the colon rather than cancer of the small intestine. On superficial examination, there appear to be several reasons why cancers of this site should be examined in detail, including:

Table 4. Observed and expected deaths and SMRs for dry cleaners exposed to perchloroethylene.

Cause*	ICD Code (7th Rev.)	Observed Deaths	Expected Deaths		SMR		
			White Rates	Black Rates	White Rates	Black Rates	Point Estimate†
MN of intestine (except rectum)	152, 153	11	6.98	6.77	182	187	182
MN of rectum	154	3	2.14	2.22	162	156	158
MN of pancreas	157	5	3.46	4.54	167	127	152
MN of respiratory system	160-164	19	14.78	16.51	148	133	140
MN of male genital organs	177-179	2	2.31	4.92	100	47	79
MN of urinary organs	180-181	5	2.84	2.92	203	198	198
MN of other and unspecified sites (major)	156B, 165, 190-199	11	7.83	8.82	162	144	156
Neoplasms of lymphatic and hematopoietic tissue	200-205	4	6.01	5.61	77	82	77
Diseases of the blood and blood-forming tissue	290-299	3	0.95	1.54	363	225	290
Diseases of the nervous system	330-334, 345	26	24.84	59.26	121	51	86
Diseases of the circulatory system	400-468	87	124.24	176.80	81	57	71
Diseases of the respiratory system	470-527	14	14.53	21.60	111	75	93
Diseases of the stomach and duodenum	540, 541, 543	4	2.01	2.39	230	193	211

*MN = malignant neoplasm.
†See text.

Table 4 (concluded)

Cause	ICD Code (7th Rev.)	Observed Deaths	Expected Deaths		SMR		
			White Rates	Black Rates	White Rates	Black Rates	Point Estimate
Hernia and intestinal obstruction	560, 561, 570	2	1.48	2.53	156	91	125
Cirrhosis of liver	581	5	7.32	10.15	79	57	67
Diseases of the genito-urinary system	590-652	6	3.67	12.69	189	55	106
Accidents	800-962	1	14.01	21.94	8	5	7
Violence	963-964, 970-985	5	6.47	12.31	89	47	65
All others		34	45.89	90.95	85	43	66
All deaths		285	284.70	473.62	97	60	93
All cancers		73	69.50	86.86	121	97	112

- o The SMR for this cause of death is substantially higher than 100.
- o There is a certain amount of clinical misclassification or incorrect diagnosis that can blur the distinction between cancer of the colon and cancer of the rectum. However, cancer of the rectum also shows a substantially elevated SMR although it is based on only three deaths. It therefore appears unlikely that the excess seen in colon cancer could result from this misclassification.
- o There appears to be a socioeconomic status gradient of risk for cancer of the colon, with the highest risk seen in individuals of high socioeconomic status. Because of the conditions of the dry cleaning industry, we believe that the cohort may be weighted toward over-representation of lower socioeconomic status individuals who seem to have an intrinsically lower risk. To the extent this belief is correct, the SMRs presented may represent underestimates.

For all these reasons, a more detailed investigation was carried out on deaths from this cause.

As seen in Table 5, the risk for colon cancer was increased for both males and females. Table 6 shows corresponding data for risk by union from this cause. Although the numbers are small the analysis suggests that the rates are considerably higher in the Oakland and Chicago unions but are still increased in the other two locals. To the extent that the small numbers permit generalization, this finding would support the belief that perchloroethylene exposure leads to an increased risk of cancer of the colon.

Table 5. Observed and expected deaths and SMRs from malignant neoplasms of the intestine (except rectum) by sex for dry cleaners exposed to perchloroethylene.

Sex	Observed deaths	Expected deaths		SMR		Point estimate SMR*
		White rates	Black rates	White rates	Black rates	
Males	5	3.08	2.75	187	209	191
Females	6	3.90	3.99	178	174	175

*See text.

Table 6. Observed and expected deaths and SMRs from malignant neoplasms of the intestine (except rectum) by union for dry cleaners exposed to perchloroethylene (those lost to follow-up and assumed to be alive).

Union	Observed deaths	Expected deaths		SMR		
		White rates	Black rates	White rates	Black rates	Point estimate*
Oakland	2	0.80	0.79	287	290	287
Detroit	4	3.35	3.17	129	137	130
Chicago	3	1.15	1.11	320	333	320
New York	2	1.67	1.69	147	146	146

*See text.

Table 7 shows the trend for colon cancer by latency.* All the deaths from this cause occurred at least 15 years after the initial known exposure to perchloroethylene, and the SMR for this cause is highest for those for whom at least 20 years elapsed since the initial known exposure to perchloroethylene, findings that are compatible with an occupational risk from perchloroethylene exposure. However, there is a potentially serious bias because of the problem discussed earlier in this report, namely, the

Table 7. Observed and expected deaths and SMRs from malignant neoplasms of the intestine (except rectum) by latency for dry cleaners exposed to perchloroethylene.

Years of latency	Observed deaths	Expected deaths		SMRs	
		White rates	Black rates	White rates	Black rates
<15	0	2.89	2.77	0	0
15- 20	3	1.83	1.80	189	192
20- 25	5	1.39	1.34	415	430
25+	2	0.88	0.83	262	278

*Because information on age distribution by latency for blacks and whites is lacking, no point estimate of the SMRs is given in the table for latency. Fortunately, the trends shown in the tables for latency are similar for both black and white rates, so the lack of a point estimate for the SMR between white and black rates for latency has no practical effect.

fact that the majority of plants had unknown solvent histories and, by default, such plants were treated as petroleum-using plants (as were the majority of plants before 1960 whose solvent history was known among plants belonging to these union locals). This means that some of the plants classified as non-perchloroethylene plants actually used perchloroethylene as a solvent.

If any of these people were employed in such plants before they began work in a plant known to use perchloroethylene, the latency for them would have been underestimated. Because this misclassification could be biased (that is, to a greater or lesser degree true for deaths from this cause than for the rest of the cohort), and because the extent of misclassification is unknown, any conclusion must be made with caution.

The risk of colon cancer was highest for those with 10 or more years exposure to perchloroethylene, a finding that is also compatible with occupationally related risk from perchloroethylene exposure. However, because of the problem of plants with unknown solvent histories, the duration of exposure is also underestimated. Because the bias for latency also exists for duration, any conclusion about the pattern of risk with duration of exposure in this study must be made with caution.

Only three deaths from malignant neoplasms of the rectum were observed. In general, the SMRs follow the same pattern discussed for malignant neoplasms for the remainder of the intestine. The small numbers preclude any definitive conclusion, but the magnitude of the SMR indicates a potential problem.

The SMR for cancer of the pancreas was elevated, based on five observed deaths. Table 8 shows the trend with latency. The increased risk was confined to those individuals with at least 20 years of latency, and there was a gradient of increasing risk with increasing latency, findings that are compatible with an occupational risk from perchloroethylene exposure. For duration of exposure, the risk was highest for those with between 5 and 10 years of known exposure to perchloroethylene, and the risk for those with

Table 8. Observed and expected deaths and SMRs from malignant neoplasms of the pancreas by latency for dry cleaners exposed to perchloroethylene.

Years of latency	Observed deaths	Expected deaths		SMRs	
		White rates	Black rates	White rates	Black rates
< 20	1	2.30	3.07	50	38
20- 25	2	0.71	0.91	325	254
25+	2	0.44	0.55	524	420

even longer known exposures to perchloroethylene was very similar to that for those with even shorter known durations of exposure to perchloroethylene. This finding would be difficult to explain by an occupational risk from known perchloroethylene exposure. However, extreme caution must be exercised before much credence can be put in these conclusions because of the serious extent of misclassification and the potential for severe bias. It is very easy to imagine that a spurious gradient of risk with increasing latency would be created or, alternatively, that a gradient of increasing risk with increasing duration could be spuriously hidden by this misclassification. The small numbers preclude an examination of risk from pancreatic cancer by union local, but it should be noted there was at least one death from this cause in each union local.

The 19 deaths from malignant neoplasms of the respiratory system comprised 17 lung cancers, 1 cancer of the larynx, and 1 cancer of other parts of the respiratory system. The risk was lowest in cohort members with under 10 years of latency and highest in those with 25 or more years of latency; but between those extremes was no consistent gradient of increasing risk with increasing latency. As noted, because of the misclassification problem, any conclusions based on the latency pattern must be made with caution. The increased risk for malignant neoplasms of the respiratory system was confined to males. This finding suggests that the risk may not be occupationally related but rather may be related to other risk factors. One strong possibility is cigarette smoking, but unfortunately no information is available on this variable.

There were five deaths from malignant neoplasms of the urinary organs, two from cancer of the kidney, and three from cancer of the bladder. The numbers are small, but because most known bladder carcinogens are also weaker kidney carcinogens* it may be reasonable to consider cancers of the urinary tract as one unit. The increased risk was seen in both sexes. Table 9 shows the pattern for latency. Although there was a very high risk for individuals with more than 25 years of latency, the risk was higher for those with less than 15 years of latency than for those with latencies between 15 and 25 years. Again because of the misclassification and bias, any conclusions from this table must be made with caution. An examination of the risk by duration of exposure shows that for these malignant neoplasms, the increased risk is confined to individuals with at least 5 years of known duration of exposure to perchloroethylene. However, the small numbers and the problems of misclassification for latency, and particularly for duration, preclude definitive conclusions.

The 11 deaths from cancer of other and unspecified sites included two cancers of the nervous system, one of bone, one of connective tissue, and seven where specific information was not available. Although this category shows an increased risk, without a more detailed breakdown of observed and expected

*This has been clearly shown for cigarette smoking, for example, by Hammond (1966) and by Kahn (1966). For study cohorts exposed to high doses of benzidine--for example, the cohort reported by Zavon et al. (1973) and by Wendel et al. (1974)--an increased risk of kidney cancer was also found, and the authors specifically stated that these renal cancers appeared to be separate primaries from the earlier appearing bladder tumors.

Table 9. Observed and expected deaths and SMRs from malignant neoplasms of urinary tract organs by latency for dry cleaners exposed to perchloroethylene.

Years of latency	Observed deaths	Expected deaths		SMRs	
		White rates	Black rates	White rates	Black rates
<15	2	1.13	1.30	204	178
15- 25	1	1.31	1.28	88	90
25+	2	0.39	0.34	592	679

deaths by anatomical site (information that was not available because of time limitations and because of the transition between contractors for data processing and for computer programming for NIOSH), it is impossible to tell whether there is a problem in one particular miscellaneous cancer.

The SMR for diseases of the blood and blood-forming organs was the highest for any individual cause of death. However, very little can be made of this observation for two reasons. First, the observation is based on only three deaths. Second, the conditions are unrelated: One death was from anemia, one was from purpura or other hemorrhagic conditions, and the third fell within the miscellaneous category of nonanemias and nonhemorrhagic conditions.

For diseases of the genitourinary system, race made a considerable difference. The point estimate gave an unremarkable SMR, but for white rates the SMR was markedly increased and for black rates the number of observed deaths was approximately half of those expected. The six deaths did not cluster within this category (two were from chronic or unspecified nephritis and other renal sclerosis, two were from kidney infections, one was from calculi, and one was from diseases of the female genital organs), which, along with the point estimate of the SMR, makes it unlikely that there is an occupationally related increased risk of death from this cause.

The most unusual finding of the study is that the SMR for all accidents was less than 10. There was one observed death from this cause, which was due to medical misadventure. This finding may be related to what we believe is the low socioeconomic status of the cohort: Perhaps no deaths were caused by motor vehicle accidents because these people cannot afford cars. (Another plausible explanation is that these people live in large cities, most of which have well developed public transportation systems, so they drive very little if at all.)

CONCLUSIONS

Because of small numbers, it appears unwise to make definitive conclusions about elevated SMRs for specific causes in this study. However, the finding of greatest concern is the SMR for cancer of the colon. The increased SMRs, based on 11 deaths from this cause, may be somewhat underestimated because of the socioeconomic status gradient for risk of this disease and the inclusion among the expected deaths of a small proportion from cancer of the small intestine. Although the number of deaths from this cause within each individual union is small, the findings of this analysis are compatible with the increased risk of colon cancer occurring in all four union locals. If this last supposition is correct (and it must be tentative because of the small numbers involved), it would suggest that the increased risk of colon cancer may be related to exposure to perchloroethylene.

Because the small numbers preclude definitive conclusions, we recommend that the study be repeated in several years. This would allow more person-years to elapse and would offer the best hope of establishing definitively whether there is a problem with cancer of the colon in this study cohort. Unfortunately, because of lack of information from sources of solvent history, no practical way exists to enlarge the number of individuals in the cohort and thereby increase the number of person-years, even though it is apparent there are many thousands of individuals who would have been included in the cohort if the records existed to allow their identification.

For several other causes of death (such as cancer of the pancreas, cancers of the urinary tract, and diseases of the blood and blood-forming organs), the SMR was increased but the numbers were small; nonetheless, an increased occupationally related risk from perchloroethylene exposure cannot be ruled out. If the cohort is updated in a few years, we recommend that special attention be paid to these other causes of death to determine whether with larger numbers an increased risk of death related to perchloroethylene exposure can either be definitely established or excluded. If this additional work is done, we recommend the following diseases be closely examined (in addition to cancer of the colon):

- Cancer of the rectum.
- Cancer of the pancreas.
- Lung cancer.
- Cancer of the kidney.
- Cancer of the bladder.
- Specific cancer, in the other and unspecified sites category in the NIOSH modified life table program.
- Specific diseases of the blood and blood-forming organs.

- Specific diseases of the stomach and duodenum.
- Specific diseases of the genitourinary system.

The most remarkable finding of the study was the very low risk for accidents. The study cohort appears to be a population that drives very little, regardless of whether the reason is economic or is due to the availability of public transportation in major metropolitan cities.

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