Cancer and other causes of death among a cohort of dry cleaners

A Blair, Patricia A Stewart, P E Tolbert, D Grauman, F X Moran, J Vaught, Judith Rayner

Abstract

Mortality among 5365 members of a dry cleaning union in St Louis, Missouri, was less than expected for all causes combined (SMR = 0·9) but slightly raised for cancer (SMR = 1·2). Among the cancers, statistically significant excesses occurred for oesophagus (SMR = 2·1) and cervix (SMR = 1·7) and non-significant excesses for larynx (SMR = 1·6), lung (SMR = 1·3), bladder (SMR = 1·7), thyroid (SMR = 3·3), lymphosarcoma and reticulosarcoma (SMR = 1·7), and Hodgkin's disease (SMR = 2·1). Mortality from emphysema was also significantly raised (SMR = 2·0). Eleven of the 13 deaths from oesophageal cancer occurred among black men. The risk of this cancer showed a significant association with estimated cumulative exposure to dry cleaning solvents (rising to 2·8-fold in the highest category) but not with level or duration of exposure. Mortality from kidney cancer was not excessive as reported in other studies. Excesses for emphysema and cancers of the larynx, lung, oesophagus, bladder, and cervix may be related to socioeconomic status, tobacco, or alcohol use. Although the number of deaths was small, the greatest risk for cancers of the lymphatic and haematopoietic system (fourfold) occurred among workers likely to have held jobs where exposures were the heaviest. Small numbers and limited information on exposure to specific substances complicates interpretation of this association but is unlikely to be due to confounding by tobacco use. It was not possible to identify workers exposed to specific dry cleaning solvents but mortality among those entering the union after 1960, when use of perchloroethylene was predominant, was similar to those entering before 1960.

Epidemiology and Biostatistics Program, National Cancer Institute, Rockville, MD 20892, USA
A Blair, P A Stewart, D Grauman
University of North Carolina, Chapel Hill, NC
P E Tolbert
Westat,Inc, Rockville, MD
F X Moran, J Vaught, J Rayner

Over the years, the dry cleaning industry has used several organic solvents including carbon tetrachloride, Stoddard solvent, tetrachloroethylene (perchloroethylene), trichloroethylene, and fluorocarbons. Stoddard solvent dominated the industry until the 1930s when carbon tetrachloride became popular. Both Stoddard solvent and carbon tetrachloride were largely replaced in the 1960s by perchloroethylene which is now used by approximately 75% of the retail dry cleaners in the United States.[1] Petroleum solvents, such as Stoddard solvent, remain the solvent of choice, however, for large industrial cleaning operations. Recently, fluorocarbons have become popular. A few other solvents such as turpentine, camphene, naphtha, and gasoline have occasionally been used, particularly during the second world war when supplies of specific chemicals were limited. Carbon tetrachloride perchloroethylene, and trichloroethylene have caused cancer in animals.[2]

With about 133 000 individuals employed in the about 20 000 dry cleaning establishments in the United States, the number of workers exposed to suspected human carcinogens could be considerable.[1] A few epidemiological studies of workers in the dry cleaning industry have been completed. Although the evidence is conflicting, these studies have suggested associations with leukaemia[3] and cancers of the lung,[4,5] cervix,[4,7] colon,[4,8] kidney,[4,7] pancreas,[4,9] bladder,[5,10] and liver.[4,10,11] We followed up our preliminary proportionate mortality investigation[4] with a cohort mortality study of workers who were members of a dry cleaning union in St Louis, Missouri, to evaluate the mortality experience of this larger population.

Methods

STUDY POPULATION

The cohort was assembled from historical dues records maintained by Local No 161 (St Louis) of the Laundry, Dry Cleaning, and Dye House Workers' International Union and includes some of the deaths covered in a previous report by the senior author.[4] Members of Local 161 worked exclusively in dry cleaning establishments. From dues records for each union member admitted before 1978, we abstracted name, social security number, date of birth, year and age of entry into the union, number of dues paying months by calendar year, race, sex, job titles (usually from around the time of entry), and most recent firm where employed. When not available from dues records, race, sex, and date of birth were sought from other sources including driver's licence records, social security files, health care finance administration records, and credit bureaus. Race or sex, or both, could not be determined for 322 union members employed for one year or more.

Vital status of study subjects on 1 January 1979 (the closing date of the study) was determined using information from union records, social security administration, motor vehicle departments, credit bureaus, state bureaus of social services, and telephone and street directories. Death certificates were coded by an experienced nosologist. Underlying and contributing causes of death were determined using the International Classification of Diseases rules in effect at the time of death and were assigned rubrics according to the eighth revision.

EXPOSURE ASSESSMENT

It was not possible to identify exposure to specific chemicals because of the large number of dry cleaning establishments (many of which had gone out of business), the changing use of solvents over the past 30 years, and the lack of historical monitoring data in these establishments. Reports of monitoring in other dry cleaning shops indicated that exposure levels to perchloroethylene and other dry cleaning solvents (Stoddard solvent and fluorocarbons) tended to be remarkably consistent from shop to shop.[12–15] Indices of exposure to dry cleaning were developed which approximate the reported measurements.

There are four major categories of jobs in the dry cleaning industry. The cleaners, who generally run the dry cleaning machines and transfer the wet clothes; the pressers and sewers who iron and repair the clothes; the counter workers who receive and dispense the clothing to the public; and other miscellaneous workers including maintenance workers (table 1). Monitoring data indicate that the cleaners probably have the highest eight hour time weighted average (TWA) owing to their proximity to the source (the washers), and that they also receive high, short term exposures during the transfer of the wet clothes.[14–16] Cleaners were, therefore, assigned an exposure index of 40 for an eight hour TWA and 60 as an index for a ceiling exposure. Pressers, sewers, and counter workers, employed in shops where dry cleaning took place, are further from the washers than the cleaners and receive their exposures from the ambient air. Their highest ceiling exposure is likely to be similar to their eight hour TWA. Therefore, they were given an index of seven for both the TWA and the ceiling. Maintenance workers were likely to have received their eight hour exposures from the ambient air, but would get high, short term ceiling exposures when repairing the washers. They were assigned a TWA of 7 and a ceiling of 60. For counter workers employed in pick up stations—that is, locations where no cleaning was done on the premises—an index of zero was assigned.

Table 1 Exposure indices based on job and type of establishment

Rank	Index	Sample job titles
		Eight hour TWA exposure
Zero	0	Counter at pickup station only
Medium	7	Counter, presser, sewer, maintenance
High	40	Cleaner
		Ceiling exposure
Zero	0	Counter at pickup station only
Medium	7	Counter, presser, sewer
High	60	Cleaner, maintenance

Several measures of exposure were used to evaluate the relation between mortality and exposure to dry cleaning solvents. Duration of union membership was used as a surrogate for duration of exposure. This measure was an imperfect measure of duration because it would underestimate work months when workers were delinquent in paying dues, or when they worked for non-union shops. On the other hand, members not employed in dry cleaning may have continued to pay dues in order to remain in the union health benefit plan, a situation where duration of membership would overestimate duration of exposure.

The estimated indices of solvent exposure were used to evaluate mortality by level, peak, and cumulative exposure. A cumulative exposure scale was developed by multiplying the exposure index for the job title (usually at entry to the union) by the number of months of union membership. For 978 subjects, however, a second job title was also available. A comparison of exposure assessments found that the exposure assessment category for the two jobs was identical for 956 of the 978 workers, indicating that job changes did not usually result in different exposures. The cumulative exposure scores were divided into terciles for analysis. Because only one job was available for most subjects, some exposure misclassification by level and cumulative exposure undoubtedly occurred. This type of misclassification is usually random, which would tend to mute exposure response gradients. Information on type of solvent used by the specific establishments where cohort members were actually employed was not available. Thus it was not possible to identify workers specifically exposed to perchloroethylene, however, separate analyses of workers first employed after 1960 focused on those most likely to have contact with perchloroethylene.

ANALYTICAL METHODS

Numbers of deaths by underlying cause among dry cleaners were compared with expected numbers based on death rates from the general United States population. Expected numbers were obtained by applying United States death rates from five year age and calendar year race sex specific categories to person-year accumulations from identical strata in the cohort. Person-year accumulation began on the date of entry to the union, or 1 January 1948 (whichever came later), and ended on the closing date of the study (1 January 1979), if alive; the data last known to be alive, if lost to follow up; or the date of death. 1 January 1948 was selected as the earliest date of entry into the follow up because union records were incomplete before that date. For analyses by number of years of union membership and cumulative level of exposure, person-years were allocated to exposure strata so that an individual's total person-years were not placed in the final membership category. Standardised mortality ratios (SMR) were obtained by dividing the number of observed deaths by the expected number. Statistical significance of SMRs was based on 95% confidence intervals constructed according to Liddell.[17] A chi-squared test was used to evaluate the statistical significance of SMR trends.[18] Standardised rate ratios (SRR) were calculated to compare death rates of heavily exposed dry cleaners to those less intensely exposed, while simultaneously adjusting for differences for race, sex, age, and calendar time by the direct method using the person-year distribution of the entire cohort as the referent population.

Results

Of the 11 062 workers holding union membership between 1945 and 1978, 5790 were members for one year or more (table 2). The 5272 who were members for less than one year were extremely difficult to trace for vital status and cumulative exposure would have been small. For these reasons, they were not included in the analyses. Of the remaining 5790 workers, 425 were missing information necessary for mortality analyses (race, sex, or date of birth) and were excluded, leaving 5365 subjects available for analysis including 407 white men, 912 black men, 2565 white women, and 1481 black women. Vital status could not be determined for 12% of the cohort (table 3). Loss to follow up was similar for white (12%) and black (13%) workers but lower among men (9%) than among women (13%). Table 4 compares subjects included in the analysis with those excluded because of missing information on race, sex, date of birth, or age at entry into the cohort. The latter had, on average, fewer years of membership (3·5 *v* 6·6), had fewer years of follow up (7·5 *v* 20·6), and had entered the union earlier (1948 *v* 1956) than subjects included in the analyses. Table 4 indicates that, on average, black men and women were union members slightly longer than white men and women (7 *v* 6 years) and were younger at entry (early 30s *v* about 40). The mean year of birth for black women was 1923 and for the other race/sex groups was before 1920. Mean duration of follow up was about 20 years for each race/sex group.

Table 5 shows mortality for selected causes of death for all race/sex groups combined. Mortality from all causes of death was significantly lower than expected (SMR = 0·9), as was death due to tuberculosis (SMR = 0·5). Twice as many deaths from emphysema occurred as expected (SMR = 2·0). The number of deaths from cancer was greater than expected (SMR = 1·2) with significant excesses occurring for cancers of the oesophagus (SMR = 2·1) and cervix (SMR = 1·7). The excess from oesophageal cancer was due to raised mortality among black men (11 of 13 deaths, SMR = 3·5). Non-significant excesses occurred for lymphosarcoma and reticulosarcoma (SMR = 1·7) and cancers of the bladder, primarily among white men and women (SMR = 1·7), and lung (SMR = 1·3). SMRs of greater than 1·5 also occurred for Hodgkin's disease (SMR = 2·1) and cancers of the larynx (SMR = 1·6) and thyroid (SMR = 3·3) but each was based on fewer than five deaths. Mortality by level of exposure is shown in table 6 for selected causes of death using SMRs and SRRs. Fewer deaths from various causes are listed in table 6 than in table 5 because some subjects lacked job titles and could not be included in exposure level analyses. For SRRs, the lowest exposure category with deaths served as the referent. No association between level of exposure and mortality from all cancer or from cervical cancer was evident. Nine of the ten deaths from cancer of the oesophagus occurred among those who held jobs in the medium exposure category and the tenth was in the highest exposure category. The risk of death from cancer of the bladder (SMR = 2·5 and SRR = 2·1 based on one death) and the lymphatic and haematopoietic system (SMR = 4·0 and SRR = 3·7) was highest in the category with the greatest estimated level of exposure to dry cleaning solvents. The exposure response trend was statistically significant (for all race/sex groups combined)

Table 2 Number of dry cleaners by race, sex, and study status

Disposition	Race/Sex					
	White men	Black men	White women	Black women	Unknown race/sex	Total
Entire cohort	805	1433	4736	2283	1805	11 062
Worked > 1 year	418	936	2609	1505	322	5 790
In analyses*	407	912	2565	1481	0	5 365

*Excluded were 425 who worked > 1 year because of missing race, sex, date of birth, or date of entry

Table 3 Tracing results by race and sex for dry cleaners with union membership of more than one year

Status	White men		Black men		White women		Black women		Total	
	No	%	No	%	No	%	No	%	No	%
Total:	407	100	912	100	2565	100	1481	100	5365	100
Alive	217	53	521	57	1715	67	1041	70	3494	65
Deceased:	157	38	306	33	545	21	214	14	1222	23
With certificates	144	35	286	31	517	20	182	12	1129	21
Presumed dead*	13	3	20	2	28	1	32	1	93	2
?, Unknown	33	8	85	9	305	12	226	15	649	12

*Reported to be dead but no death certificate available

Table 4 Means of selected variables for subjects (included and not included in the analyses) with union membership of more than one year

Year	Included					Not included
	White men	Black men	White women	Black women	Total	Not included
Year of birth	1914	1919	1916	1923	1919	NA
Age at entry	39	34	41	32	37	NA
Year of entry	1954	1954	1957	1956	1956	1948
Years of membership	6·0	6·9	6·1	7·3	6·6	3·5
Years of follow up	20·6	21·9	20·1	20·7	20·6	7·5

Table 5 Mortality among 5365 dry cleaners for selected causes of death

Cause (ICDA 8th rev)	SMR†	Obs exp	95% CI
All causes	0·9*	1129·1267·9	0·9 1·0
Infective and parasitic diseases (000-009)	0·6	15·23·2	0·3 1·1
Tuberculosis (010-019)	0·5*	6·13·1	0·2 1·0
All cancers (140-209)	1·2*	294·254·2	1·0 1·3
Buccal cavity and pharynx (140-149)	1·0	5·5·2	0·3 2·2
Oesophagus (150)	2·1*	13·6·1	1·1 3·6
Stomach (151)	0·8	11·13·9	0·4 1·4
Colon (153)	1·0	25·25·6	0·6 1·4
Rectum (152)	1·4	10·7·3	0·7 2·5
Liver (155, 156)	0·7	5·7·3	0·2 1·7
Pancreas (157)	1·2	15·12·7	0·7 1·9
Larynx (161)	1·6	3·1·9	0·3 4·7
Lung (162, 163)	1·3	47·37·1	0·9 1·7
Skin (172, 173)	0·8	2·2·6	0·1 2·8
Breast (174)	1·0	36·36·3	0·7 1·4
Cervix uteri (180)	1·7*	21·12·4	1·0 2·6
Corpus uteri (181)	1·0	8·8·0	0·4 2·0
Prostate (185)	0·7	5·7·0	0·2 1·7
Bladder (188)	1·7	8·4·8	0·7 3·3
Kidney (189)	0·5	2·4·0	0·1 1·8
Brain (191, 192)	0·2	1·4·6	0·0 1·2
Thyroid (193)	3·3	3·0·9	0·7 9·8
Lymphatic/haematopoietic (200-209)	1·2	24·20·0	0·8 1·8
Lymphosarcoma/reticulosarcoma (200)	1·7	7·4·2	0·7 3·4
Hodgkin's disease (201)	2·1	4·1·9	0·6 5·3
Leukaemia (204-207)	0·9	7·7·9	0·4 1·8
Other lymphatic (202, 203, 208)	0·7	4·5·8	0·2 1·8
Arteriosclerotic heart disease (410-414)	1·0	314·323·6	0·9 1·1
Pneumonia (480-486)	1·2	35·29·8	0·8 1·6
Emphysema (492)	2·0*	14·7·0	1·1 3·4
Cirrhosis of liver (571)	1·0	24·24·2	0·6 1·5
Chronic nephritis (582)	0·6	6·10·7	0·2 1·2
Senility and ill defined conditions (780-796)	0·8	18·21·4	0·5 1·3
Motor vehicle accidents (810-819)	0·7	16·21·7	0·4 1·2
Suicide (950-959)	1·0	16·9·6	0·5 1·9

Number of person-years = 98 818
*p < = 0·05.
†Age calendar year/race/sex adjusted SMR.

Table 6 Observed and expected numbers of deaths and relative risks for selected cancers by level of exposure to dry cleaning solvents

	Exposure*	White men	Black men	White women	Black women	Total SMR	Total SRR
Cancer	Low	1 140 0 23	14 7 8 1 7	57 41 9 1 4	10 10 3 0 5	84 64 4 1 3	1 05
	Medium	13 11 4 1 0	44 29 8 1 5	76 58 1 1 0	35 34 9 1 0	170 157 3 1 1	1 09
	High	10 6 2 1 6	7 7 9 0 9	8 1 2 0 0 3		12 15 6 1 1	1 11
	χ² test for trend = 0 445						
Oesophagus	Low	0 0 1	0 0 5	0 0 4	0 0 3	0 1 2	
	Medium	1 0 3 2 9	7 1 9 3 6	1 0 2 1 3	0 0 8	9 3 8 2 4	1 0
	High	0 0 2	1 0 5 2 0	0 — 0 1	0 — 0 1	1 0 7 1 5	1 3
	χ² test for trend = 0 102						
Cervix	Low			5 1 9 2 6	2 1 4 1 1	7 3 3 — 1	1 0
	Medium			4 3 6 1 1	1 6 1 5	11 8 2 1 3	0 7
	High			0 0 1	0 — 0 1	0 0 1	
	χ² test for trend = 0 882						
Bladder	Low	0 0 1	0 0 2	3 0 0 1 8	0 0 2	3 1 1 2 7	1 0
	Medium	1 0 0 1 6	1 0 0 1 3	— 1 2 1 7	0 0 0	4 3 0 1 4	0 6
	High	1 0 2 1 8	0 0 2	0 — 0 1	0 — 0 1	1 0 4 2 5	2 1
	χ² test for trend = 0 111						
Lymphatic & haematopoietic	Low	0 0 1	0 0 6	4 5 9 2 0	0 0 1	7 9 1 1 4	1 0
	Medium	4 1 3 0 8	1 2 1 0 5	6 6 0 0 9	1 2 2 0 1	9 12 9 0 7	0 6
	High	1 0 6 2 0	1 0 6 1 8	0 0 1	0 — 0 1	3 1 5 4 0	3 7
	χ² test for trend = 2 63;						

*Exposure level: based on table 1. Low = 0; medium = 1; high = 10.
†Observed and expected numbers.
‡SMR.
§Referent category is low or category with deaths.

for cancers of the lymphatic and haematopoietic system but not for bladder cancer. Numbers were too small to evaluate an exposure response trend for specific race sex groups but the excess of lymphatic and haematopoietic cancer occurred primarily among white men.

Analyses by duration, peak, and cumulative exposure did not uncover any significant trends, although for cancer of the oesophagus the excess occurred in the highest of the three cumulative exposure categories (SMRs of 0·9, 0·5, and 2·8 for low, medium, and high categories, respectively). Comparison of relative risks among workers first employed before 1960 with those first employed after 1960 showed similar patterns, suggesting that those who were more likely to be exposed to perchloroethylene were not experiencing unusual mortality. Analyses by time since first exposure were uninformative.

Discussion

Epidemiological studies of dry cleaners have shown excesses for several cancers, including leukaemia and cancers of the kidney, bladder, lung, cervix, liver, skin, and pancreas.[1–10] Findings have not been consistent between the studies, although excesses for cancer of the urinary system have occurred in several reports.[1 7] These excesses are intriguing in the light of the renal tubular karyomegaly and hyperplasia seen in rats exposed to perchloroethylene.[10] No excess of kidney cancer occurred in this cohort (2 observed, 4 expected deaths) but there was a slight, but non significant, excess mortality from bladder cancer (SMR = 1·7) that occurred in all race/sex groups except black women. Mortality from bladder cancer was greater among those holding jobs where exposure was likely to have been heavier (SRR = 2·1) than among those in the least exposed jobs (SRR = 1·0) but only one death occurred in the high category. SMRs, however, did not show a positive association with exposure level, which indicates differences in ages between subjects in the various exposure categories. Bladder cancer has been raised in other cohort mortality studies of dry cleaners.[1 3 6] There was no excess for bladder cancer in a case control study in Iowa,[2] but a significant excess occurred among black men in a study conducted by the UNCU in the late 1970s.[4 5] In these case control studies relative risks were adjusted for smoking, something not possible in this, or most other, cohort studies.

The risk of lymphatic and haematopoietic cancer was significantly correlated with level of exposure, rising to about fourfold in the high exposure category (SMR = 4·0, SRR = 3·7), although there were only five deaths in this category. Deaths from lymphoma and Hodgkin's disease were raised whereas there was a slight deficit of leukaemia. This contrasts with excesses of leukaemia reported by others,[1 2 5 6] which is of interest given the excess of leukaemia occurring among rats exposed to perchloroethylene.[10]

Cancer of the cervix was significantly increased (SMR = 1·7) but the greatest risk occurred among women holding jobs with little or no exposure (SMR = 2·1), suggesting that socioeconomic and non occupational factors[11] associated with the aetiology of this tumour may be involved. The slight excess of lung cancer did not rise with increasing level of exposure, suggesting that it may be due to tobacco use, since emphysema was also increased. Fewer deaths from liver cancer occurred than expected, in contrast to excesses reported in other epidemiological studies[4 6 10] and among mice exposed to perchloroethylene.[10]

The striking excess of oesophageal cancer among black men (SMR = 3·5) was not seen in other race/sex groups and mortality from this cancer has not been reported as excessive in other studies. Although socioeconomic status, tobacco, and alcohol are strong risk factors for this cancer[12] and may confound this association, the significantly raised risk in the highest cumulative exposure category (SMR = 2·8) suggests that this site should be looked at in other populations exposed to solvents.

Certain limitations of these data must be considered in interpreting the results. Information on tobacco and alcohol used among members of this cohort was not available. Data from other sources, however, suggest that dry cleaners may smoke more than members of other occupations.[2 13] Since alcohol use often parallels tobacco use, dry cleaners may also drink more than other occupational groups. No excess was noted, however, for cirrhosis of the liver, often due to excessive consumption of alcohol. Raised mortality from many of the tobacco related causes of death (emphysema and cancers of the oesophagus, larynx, lung, cervix, and bladder) also suggests that socioeconomic status, tobacco, and alcohol use may explain some of the excesses observed. Smoking has not been reported however, as a strong risk factor for lymphatic and haematopoietic cancer, which was also increased in this cohort. A second limitation is that the significant deficit of deaths from all causes indicates that the "healthy worker effect" was operating[14] and that relative risks may have been underestimated for specific causes of death. Internal comparisons using direct age race sex adjustments (SRRs) partially corrects for this problem by providing a comparison of relative risks of workers more heavily exposed with those with lesser exposure. Unfortunately small numbers limit the usefulness of this approach. A third limitation is that with the vital status of 12% of the cohort unknown, some deaths have probably been missed, which may again result in underestimates of relative risks. Potentially for some cancers of interest here mortality may not be an accurate reflection of incidence. Cancers of the liver, cervix, and certain leukaemias may be particularly problematical.[15] Finally, little information was available to estimate exposures. Usually only the job held when first joining the union was available and subsequent job changes were not. Moreover, no information was available on specific chemicals used. Although we developed an index of exposure it was based on published information not on measurements in plants included in this study. Relative risks for any particular chemical are likely to be diluted by inclusion of unexposed subjects or by misclassification of exposures in those categories which would tend to reduce estimates of relative risk and to limit exposure response relations.

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1 Blair A, Stewart P, Tolbert PE, Grauman D, Moran EC, Vaught J, Rayner J. Cancer and other causes of death among a cohort of dry cleaners. *Br J Ind Med* 1990;47:162–8.
2 International Agency for Research on Cancer. *Allyl compounds, aldehydes, epoxides and peroxides. IARC monographs on the evaluation of carcinogenic risk of chemicals to humans*. Vol 36. Lyon: IARC, 1985.
3 US Bureau of the Census. *County business patterns*. Washington DC: US Government Printing Office, 1977. (DHEW publication (OHP) 75-1.)
4 Blair A, Decoufle P, Grauman DJ. Cancer and other causes of death among laundry and dry cleaning workers. *Am J Public Health* 1979;69:508–11.
5 Berman DW, Robinson CD, Freedman R. *Mortality experience of army world war II chemical specialty companies*. *J Occup Med* 1983;25:658–62.
6 Doll R, Asal NR. Mortality among laundry and dry cleaning workers in Oklahoma. *Am J Public Health* 1980;70:1258–59.

7 Katz RM, Jowett D. Female laundry and dry cleaning workers in Wisconsin: a mortality analysis. *Am J Public Health* 1981;71:305–7.
8 Brown DP, Kaplan SD. Retrospective cohort mortality study of dry cleaning workers using perchloroethylene. *J Occup Med* 1987;29:535–41.
9 Lin RS, Kessler II. A multifunctional model for pancreatic cancer in man. *JAMA* 1981;245:147–52.
10 Stemhagen A, Slade J, Altman R, Bill J. Occupational risk factors and liver cancer. *Am J Epidemiol* 1983;117:443–54.
11 Hernberg S, Korkala M, Asikainu U, Riala R. Primary liver cancer and exposure to solvents. *Int Arch Occup Environ Health* 1984;54:147–53.
12 Materna BL. Occupational exposure to perchloroethylene in the dry cleaning industry. *Am Ind Hyg Assoc J* 1985;46:268–73.
13 National Institute for Occupational Safety and Health. *Criteria for a recommended standard ... occupational exposure to tetrachloroethylene (perchloroethylene)*. Cincinnati: NIOSH 1976. (HEW publ No (NIOSH) 76–185.)
14 National Institute for Occupational Safety and Health. *Engineering control technology assessment of the dry cleaning industry*. Cincinnati: NIOSH, 1980. (DHHS (NIOSH) publ No 80–136.)
15 Ludwig HR, Meister MV, Roberts DR, Cox C. Worker exposure to perchloroethylene in the commercial dry cleaning industry. *American Industrial Association Journal* 1983;44:600–5.
16 Ludwig HR. *Occupational exposure to perchloroethylene in the dry cleaning industry*. National Institute for Occupational Safety and Health, 1981. (Internal report; DHSS.)
17 Liddell FDK. Simple exact analysis of the standardised mortality ratio. *J Epidemiol Community Health* 1984;38:85–8.
18 Breslow NE, Lubin JH, Marek P, Langholz B. Multiplicative models and cohort analysis. *Journal of the American Statistical Association* 1983;78:1–12.
19 National Toxicology Program. *Toxicology and carcinogenesis studies of tetrachloroethylene (perchloroethylene) (CAS No 127-18-4) in F344/N rats and B6C3F1 mice (inhalation studies)* (Tech Rep Ser No 311, NIH No 86–2567). Research Triangle Park, US Department of Health and Human Services, 1986.
20 Smith EM, Miller ER, Woolson RF, Brown CK. Bladder cancer risk among laundry workers, dry cleaners, and others in chemically-related occupations. *J Occup Med* 1985;27:295–7.
20a Silverman DJ, Levin LI, Hoover RN. Occupational risks of bladder cancer in the United States: II. Nonwhite men. *JNCI* 1989;81:1480–3.
21 Cramer DW. Uterine cancer. In: Schottenfeld D, Fraumeni JF, eds. *Cancer epidemiology and prevention*. WB Saunders, 1982:881–900.
22 Day NE, Munoz N. Esophagus. In: Schottenfeld D, Fraumeni JF, eds. *Cancer epidemiology and prevention*. WB Saunders, 1982:596–623.
23 Walrath J, Rogot E, Murray J, Blatt A. *Mortality patterns among US veterans by occupation and smoking status*. Vol I. Bethesda: US Department of Health and Human Services, 1985. (NIH publication No 85–2756.)
24 Sterling TD, Weinkam JJ. Smoking characteristics by type of employment. *J Occup Med* 1976;18:743–54.
25 McMichael AJ. Standardised mortality ratios and the "healthy worker effect": scratching beneath the surface. *J Occup Med* 1976;18:165–8.
26 Percy C, Stanek E, Gloeckler L. Accuracy of cancer death certificates and its effect on cancer mortality statistics. *Am J Public Health* 1981;71:242–50.

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Mortality and incidence of cancer among Swedish gas workers

P Gustavsson, Christina Reuterwall

Abstract

The mortality and incidence of cancer was studied among 295 workers at a Swedish gas production company. All men employed for at least one year between 1965 and 1972 were included in the study. The follow up period for mortality was 1966 to 1986, and the incidence of cancer was followed up from 1966 to 1983. Expected numbers of deaths were based on local death rates among occupationally active men, the expected numbers of cancer were based on national statistics. The total mortality was increased, mainly due to an excess of deaths from circulatory diseases. The excess was larger after long follow up and after long employment periods. Two cases of cancer in the nose and nasal sinuses were found; there was no excess of lung cancer. Smoking habits were investigated for a subset of the cohort and did not differ from the average for men in large cities. The findings are discussed in relation to other studies of soot and combustion exposed workers.

Coal gas is produced by dry distillation of bituminous coal. Coke, the residue after distillation, is formed as a byproduct.

The Stockholm Gas Company has produced gas since the middle of the nineteenth century. The current plant started in 1893 and coal gas was produced in coke ovens from around 1918 to 1972. Before 1918 the gas was produced in retorts and since 1972 gas has been produced by cracking of petroleum products. The coke ovens were similar to those in a coke plant and coke was an important byproduct. Around 150 000 000 m^3 gas and 300 000 metric tons coke were produced annually in the period 1950–70.

Gas and coke workers are exposed to gas and smoke from the ovens. The first study indicating an increased risk of cancer for gas workers was published in 1936, when Kuroda and Kawahata reported an excess of lung cancer at a Japanese gas plant.[1] Excesses of cancer of the lung and bladder were later reported among 2449 British gas workers[2] and an excess of lung cancer was also found in a small cohort of Danish gas workers.[3] Several case reports indicate that gas workers are also at increased risk for skin cancer. Polycyclic aromatic hydrocarbons (PAH) have been pointed out as the most probable cause of the excess risks.[4]

The International Agency for Research on Cancer (IARC) evaluated the cancer hazards for gas production workers and concluded that there was sufficient evidence that coal tar from destructive distillation of coal in gas works causes skin cancer in man and there was also sufficient evidence that certain exposures in retort houses of older coal gasification processes are carcinogenic and give rise to lung cancer in man.[4] There was limited evidence that such occupational exposures also cause bladder cancer. No data were available for exposures in newer processes.

The occupational exposures associated with coal gas production have several similarities with those in coke plants, where coke is produced for metallurgical purposes and gas is a byproduct. An excess of lung cancer was reported among 4661 workers in 12 coke plants in the United States and Canada. There was also a tendency towards increased mortality in cancer of the kidney and prostate.[5,6]

An excess of lung cancer was found among 6767 English coke production workers (SMR = 117)[7] and among 1269 French coke production workers (SMR = 251).[8]

An investigation of the mortality and incidence of cancer at a Swedish coke plant was first published in 1979[9] and the study was updated in 1987.[10] There was an increased mortality from ischaemic heart disease but no definite indications of an excess of lung cancer in this small cohort.

Thus there is strong evidence for an increased risk of lung cancer among coke and gas workers, possibly caused by exposure to PAH. In recent years an increased risk for atherosclerotic disease has also been reported among workers exposed to combustion products and PAH. Excesses of ischaemic heart disease were found among Swedish chimney

Department of Occupational Medicine, Karolinska Hospital, Stockholm, Sweden
P Gustavsson
Division of Occupational Medicine, National Institute of Occupational Health, Solna, Sweden
C Reuterwall