Scand J Work Environ Health 1987;13(2):108-117

<https://doi.org/10.5271/sjweh.2073>

Issue date: Apr 1987

Mortality of chrome leather tannery workers and chemical exposures in tanneries.

by [Stern FB](#), [Beaumont JJ](#), [Halperin WE](#), [Murthy LI](#), [Hills BW](#), [Fajen JM](#)

The following article refers to this text: [1987;13\(6\):529-531](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/3602964

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Mortality of chrome leather tannery workers and chemical exposures in tanneries

by Frank B Stern, MS,¹ James J Beaumont, PhD,² William E Halperin, MD, MPH,¹ Leela I Murthy, PhD,¹ Bruce W Hills, MS,¹ John M Fajen, MS¹

STERN FB, BEAUMONT JJ, HALPERIN WE, MURTHY LI, HILLS BW, FAJEN JM. Mortality of chrome leather tannery workers and chemical exposures in tanneries. *Scand J Work Environ Health* 13 (1987) 108–117. A retrospective mortality analysis was conducted in a cohort of 9 365 individuals employed as of 1940 in two chrome leather tanneries in the United States and followed to the end of 1982. Vital status as of the closing date was determined for over 95 % of the cohort. Potential hazardous workplace exposures varied with department and included nitrosamines, chromate pigments, benzidine-based direct dyestuffs, formaldehyde, leather dust, and aromatic organic solvents. Mortality from all causes combined was lower than expected for each tannery, the standardized mortality ratio being 81 for one and 93 for the other. Deaths from cancer of each site, including the lung, were also lower than expected compared to those of either the population of the United States or of local state rates. A significant excess of deaths was observed, however, due to accidental causes in one tannery and cirrhosis of the liver, suicide, and alcoholism in the other. These excesses did not appear to be causally associated with occupational exposures. The findings of this study are consistent with those of the only other mortality investigation of leather tannery employees.

Key terms: cancer, occupational exposures, retrospective study.

Employment in the leather and leather manufacturing products industry, Standard Industrial Classification (SIC) 31 (43), has been associated with cancer of the bladder, lung, larynx, buccal cavity and pharynx, kidney, nasal cavity, lymphoma, and cirrhosis of the liver (1, 2, 6, 9, 10, 12, 15, 17, 18, 19, 22, 23, 26). These reports have included tanners, shoemakers, repairers, and other unspecified "leather workers" in their analyses. The present report focuses specifically on that subgroup of employees in SIC 31 engaged in the tanning and finishing of leather (SIC 311) and excludes those employees converting finished leather into products. Employees engaged in the chrome tanning and finishing of leather have potential for exposure to numerous known or suspected occupational carcinogens including hexavalent chromium salts, benzidine-based azo dyes, aromatic organic solvents, formaldehyde, and airborne leather dust (21, 23). N-nitrosodimethylamine (NDMA), a liver and kidney animal carcinogen and one of the 13 occupational carcinogens regulated by the Occupational Safety and Health Administration (OSHA) (11), has also been detected in the work environment of various tanneries (15, 32).

Tanning is a process by which hides and skins are converted into finished leather by the removal of the

epidermis and subcutaneous layer of the hide and the subsequent stabilization of the middle portion (derma). Two main processes for leather are used in the United States (US). Vegetable tanning extracts are utilized to produce firmer, thicker leathers for bags, cases, strap leathers, and for shoe soles and heels; trivalent basic chromic sulfate is used to produce softer, thinner leathers for personal leather goods such as handbags, gloves, garments, upholstery, and the upper parts of shoes. Approximately 85 % of all leather produced in the United States is chrome tanned (personal communication from Dr R Lollar, Technical Director of the Leather Industries of America); therefore, employees involved in producing chromed leather were the focus of our investigation.

A description of the processes (21) and potential hazardous chemical exposures (13, 14) for the chrome leather tanneries that were studied is presented in table 1. No previous environmental analyses had ever been conducted at either tannery. The processes in the two tanneries have remained relatively the same since the end of the 19th century. However, some mechanization and chemical technology have been introduced to reduce the amount of manual operations. For example, rotating drums and hide processors, in which chemicals are often introduced through fixed pipes, have replaced the paddle vats for soaking, dehairing, and tanning the hides. Various chemical changes have included, among others, the use of dimethylamine sulfate (DMAS) as an accelerating agent in the dehairing process, chlorophenols as a disinfecting agent, and trivalent instead of hexavalent chromium salts as the tanning material. Some of these chemicals (eg, dimethylamine sulfate and the chlorinated phenolic

¹ National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, United States.

² University of California at Davis, Department of Internal Medicine, Davis, California 95616, United States.

Reprint requests to: Mr FB Stern, National Institute for Occupational Safety and Health, Robert A Taft Laboratories, 4676 Columbia Parkway, Cincinnati, OH 45226, USA.

Table 1. Process description and chemicals sampled in two leather tanning facilities.

Process (by department)	Process description	Chemicals sampled in each department	Number of samples	Concentration ^a	
				Range	Mean
<i>Beamhouse</i>					
Receive, sort, trim and side	Receive, sort, and trim the perimeter areas of the hide and split the hide in half (from tail along the backbone to center of neck)	.	.	.	.
Soak and wash	Remove blood, dirt, manure, and excess salt and restore moisture to open up the contracted fibers so they are chemically active.	.	.	.	.
Dehair	Destroy the hair using hydrated lime containing accelerating agents (eg, sulfide chemicals and dimethylamine sulfate)	Hydrogen sulfide N-nitrosodimethylamine (produced from dimethylamine sulfate)	3 29	0—2.0 0—11 ^b	1.3 3.5 ^b
Flesh	Remove excessive flesh, fat, and muscle	.	.	.	.
Delime and bate	Neutralize the high alkalinity of the limed hides with buffering salts (eg, ammonium sulfate or ammonium chloride)	Ammonia Sulfuric acid	2 6	9—30 0—0.24	19.5 0.12
Pickle	Place the hide in an acid envi- ronment ready to accept the tanning material using a solution of sodium chloride and sulfuric acid	.	.	.	.
<i>Tanyard</i>					
Tan	Convert the raw collagen fibers of the hide into a stable product which is no longer susceptible to rotting by placing the hides in a drum containing basic trivalent chromic sulfate solutions	Total chrome including chromium (VI) (air) Total chrome (%) (bulk sample)	55 5	0.2—54 ^b 1.5—3.8	38.8 ^b 2.7
Wring	Remove excess moisture to ease splitting	.	.	.	.
Split and shave	Adjust thickness of the hide	.	.	.	.
<i>Retan, color, fat-liquoring</i>					
Retan	Add tanning agents such as vege- table and synthetic tannins to modify the physical properties of the leather	.	.	.	.
Color	Color the leather using acid, metallic, basic, or direct dyes	Formic acid Benzidine in bulk dyes Copper	19 2 2	1.3—6.7 2.0—55 0.0—0.0	3.0 28.3 0.0
Fat-liquoring	Lubricate the leather with animal oil to give it pliability and tensile strength	Cobalt Manganese Cadmium	2 2 2	0.0—0.0 0.0—0.0 0.0—0.0	0.0 0.0 0.0
Dry	Remove excess moisture	.	.	.	.
Set out	Smooth and stretch the leather	.	.	.	.
<i>Finishing</i>					
Condition, stake, buff, finish, plate, measure, grade	Mechanical and chemical operations that soften, smooth, and help preserve the leather	N-butyl acetate Butyl cellosolve Methyl ethyl ketone Methyl isobutyl ketone Toluene Xylene Acetone Formaldehyde Airborne leather fibers Copper Cobalt Manganese Cadmium Respirable dust	27 69 26 83 83 83 83 5 22 2 2 2 2 3	0.0—0.0 0.2—12 0.0—0.0 0.3—51 0.2—206 0—48 0.3—105 0.5—7 ^c 0.2—3.9 ^d 0.0—0.0 0.0—0.0 0.0—0.0 0.0—0.0 0.0—0.0	0.0 1.6 0.0 6.5 26.1 15.1 13.9 2.45 ^c 0.26 ^d 0.0 0.0 0.0 0.0 70 %
<i>All other (mainly maintenance and support)</i>					
.	.	.	.	.	.

^a Parts per million unless otherwise specified.^b Micrograms per cubic meter.^c The 8-h time-weighted average standard of the US Occupational Safety and Health Administration is 3 ppm.^d Milligrams per cubic meter.

biocides), however, have since been replaced in the past decade due to concern about their health consequences. With new technologies, the increased importation of finished leather goods (mainly from Italy), and the greater use of man-made materials, the number of workers employed in the US tanning industry has declined from a peak of 33 000 in 1965 (29) to approximately 20 000 as of 1982 (38).

Subjects and methods

The study cohort included all production workers employed between 1 January 1940 and 11 June 1979 at tannery A ($N = 2\ 807$) or between 1 January 1940 and 1 May 1980 at tannery B ($N = 6\ 558$). The cohort members were identified from the personnel records, which generally contained name, social security number, sex, race, date of birth, date of hire, date of separation, and specific work history information (ie, department, job assignment and dates of each new work assignment). No information on country of birth (emigration) was available from the employment records.

The vital status of each member of the cohort was determined as of 31 December 1982 from records of the Social Security Administration, Internal Revenue Service, or the National Death Index (NDI) (34), among others. For each cohort member identified as deceased, a death certificate was obtained from the appropriate state vital statistics office, and underlying and contributory causes of death were coded by a qualified nosologist, according to the revision of the International Classification of Diseases (ICD) in effect at the time of death. Deceased employees for whom no death certificate could be obtained were assumed dead as of the date given by the reporting agency, and the cause of death was classified as unknown.

A modified life-table analysis system (41) was utilized to accumulate the person-years at risk for each study member beginning with the first day of employment at either tannery after 1 January 1940 until either 31 December 1982 or the date of death, whichever came earlier. The person-years at risk were classified by sex, race, five-year age groups and calendar-time periods, employment periods, and latency periods (time periods since first employment). They were then multiplied by the appropriate sex-, race-, age-, and cause-specific mortality rates of the US population to yield the number of expected deaths. Expected mortality was similarly computed with the use of the state death rates of Minnesota for tannery A and Wisconsin for tannery B in order that possible variations in mortality patterns between state and national rates due to population composition and geographic location could be controlled for. For site-specific cancers, state death rates for the years 1950–1979 were utilized; for other causes, state death rates for the years 1962–1979 were used (according to the unpublished data of GM March,

Mortality and Population Data System, University of Pittsburgh).

Duration of employment was used in the analysis as a surrogate for cumulative exposures since past environmental monitoring data from the tanneries were not available. Categories for analysis by duration of employment (< 1 year, 1–9 years, and ≥ 10 years) were established from an examination of the distribution of the person-years at risk. For cancers, a minimum latency period of 15 years was selected since most occupationally related cancers usually occur after an appropriate induction-latency period (8). Observed and expected numbers of deaths were also stratified according to “ever having been employed” within certain departments of the tannery. The departments were grouped according to process description and chemical exposures as presented in table 1. For most employees, potential for exposures depended upon the department (area) in which they worked, although it was realized that exposures between departments could overlap.

A standardized mortality ratio (SMR) was computed for each cause of death by multiplying the ratio of the observed to the expected number of deaths by 100. A two-sided confidence limit (95 %) for each SMR was then calculated on the assumption of a Poisson distribution for the observed deaths (31). When the confidence interval did not include 100, the SMR value was considered statistically significant.

Results

Cohort description

Through 31 December 1982, 95 % of the 9 365 members of the cohort were successfully traced: 7 316 individuals (78 %) were alive, 1 582 individuals (17 %) were deceased, and 467 individuals (5 %) were lost to follow-up and considered alive for the purposes of our study (table 2). Death certificates were obtained for 96.8 % of all deaths. Of the 9 365 individuals in the cohort, 5 827 (75.7 %) were male, and 2 280 (24.3 %) were female. Approximately 18 % of the cohort was nonwhite.

The mean age of the cohort at hire was 27 years. More than one-half of the workers (52 %) were hired prior to 1960. Thus the majority of the work force had a minimum of 22 years between date of hire and 1982 (the ending date of the study). For tannery A, 21 % of the workers were employed for 10 years or longer. For tannery B, only 8 % were employed for 10 years or longer. These percentages indicate a fairly substantial employment turnover rate at both tanneries, somewhat typical of the US leather tanning industry.

Total deaths

The 1 582 deaths observed among the workers from both tanneries combined were 89 % of the number ex-

pected based upon US age-adjusted mortality rates (table 3). Statistically significant deficits of deaths from all causes combined were observed for both tannery A (SMR 81, 95 % CI 74—88) and tannery B (SMR 93, 95 % CI 88—100). This reduction in mortality for each tannery was due to decreased risks of death from most causes. Significant elevations in mortality, however, were found for accidents in tannery A and for alcoholism, cirrhosis of the liver, and suicide in tannery B.

Cancers

The number of deaths from all cancers combined was less than expected for both tannery A and tannery B despite whether US rates or state death rates were used for the comparison (table 4). (The discussion of the cancer results has been limited to findings based on

state, rather than US, death rates since regional rates were thought to control better for possible variations in mortality patterns.) The “all cancers” deficit was largely explained by a reduced number of deaths from cancers of the trachea, bronchus, and lung. Analysis by duration of exposure for these subsites of cancer showed an absence of any positive correlation with excess mortality risk when examined after a time period of 15 years from first exposure, the SMR for 10 years employment being the lowest (table 5). Deficits in mortality from cancers of the trachea, bronchus, and lung were also observed within each department of the tanneries (table 6).

All other primary sites of cancer mortality were also below expectation (table 4). Specifically, for cancers of the buccal cavity and pharynx, eight deaths were observed for both tanneries combined (with 8.5 expected), all resulted after a 15-year latency period (table

Table 2. Vital status of the cohort members of two leather tanneries by sex and race, 31 December 1982.

Vital status	Males				Females				Total cohort	
	White		Nonwhite		White		Nonwhite		Number	Percentage
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage		
Alive	4 376	75	1 037	82	1 549	82	354	92	7 316	78
Deceased	1 219	21	137	11	216	11	10	3	1 582	17
Death certificates obtained	1 184	-	125	-	213	-	10	-	1 532	-
Death certificates outstanding	35	-	12	-	3	-	0	-	50	-
Lost to follow-up	232	4	84	7	132	7	19	5	467	5
Total cohort	5 827	100	1 258	100	1 897	100	383	100	9 365	100
Person-years at risk	129 654		19 741		49 324		5 543		204 262	

Table 3. Mortality experience for selected causes among employees of two leather tanneries, 1940—1982.^a

Cause of death ^b	Both tanneries				Tannery A				Tannery B			
	Observed deaths	SMR ^c	95 % CI ^d		Observed deaths	SMR ^c	95 % CI ^d		Observed deaths	SMR ^c	95 % CI ^d	
All cancers (140—205)	282	79*	70—89		104	78*	64—95		178	80*	69—93	
Alcoholism (322)	12	148	76—259		1	-	-		11	192*	101—344	
Nervous system diseases (330—334)	109	80*	66—97		48	91	67—121		61	74	56—96	
Circulatory system diseases (400—468)	620	85*	78—92		239	76*	67—87		381	91	82—101	
Respiratory system diseases (470—527)	89	93	74—114		35	87	61—122		54	99	73—127	
Cirrhosis of the liver (581)	52	114	85—150		7	44*	18—92		45	150*	110—201	
Genitourinary system diseases (590—652)	19	81	49—126		7	83	33—172		12	79	41—139	
Accidents (E800—E959)	144	105	89—124		65	128*	101—163		79	92	73—115	
Suicide (E963, E970—E979)	58	143*	109—185		16	99	56—161		42	171*	123—232	
Homicide (E964, E980—E985)	22	76	46—111		1	-	-		21	85	53—130	
All causes (001—998) ^e	1 582	89*	85—94		568	81*	84—88		1 014	93	88—100	

^a Based upon United States mortality rates.

^b The code of the International Classification of Diseases, seventh revision, is given in parentheses.

^c Standardized mortality ratio (observed/expected) × 100, not calculated for observed number of deaths less than 2.

^d 95 % confidence interval (two-sided test).

^e Includes unknown causes.

* P < 0.05.

Table 4. Mortality experience for selected causes of cancer among employees of two leather tanneries, 1950–1982. Comparison with the United States (US) death rates and with the Minnesota (tannery A) and Wisconsin (tannery B) state death rates.

Cause of death ^a	Tannery A				Tannery B			
	Observed deaths	SMR ^b (US)	SMR ^b (Minnesota)	95 % CI ^c (Minnesota)	Observed deaths	SMR ^b (US)	SMR ^b (Wisconsin)	95 % CI ^c (Wisconsin)
All cancers (140–205)	99	78	88	72–107	177	84*	82	73–98
Buccal cavity and pharynx (140–148)	3	78	102	21–301	5	83	88	29–207
Digestive organs and peritoneum (150–159)	38	104	107	76–148	56	96	94	71–124
Liver (155–156 ^a)	1	.	.	.	7	123	101	28–269
Respiratory (160–164)	19	46	66	40–104	45	78	95	70–128
Trachea, bronchus, lung (162–163)	18	47	67	40–106	42	77	93	67–126
Genitourinary tract (171–182)	16	84	89	51–145	24	75	75	48–112
Kidney (180)	4	133	119	33–307	4	93	79	22–202
Bladder (181)	1	.	.	.	4	83	98	27–253
Other and unspecified (190–199)	15	102	116	65–192	21	83	71	45–107
Lymphatic and hemopoietic system (200–205)	8	65	58	25–116	14	72	74	42–123
Leukemia and aleukemia (204)	4	77	70	19–180	6	75	75	28–164
Lymphoma (200–203, 205)	4	57	51	14–129	8	70	66	29–131

^a The code of the International Classification of Diseases, seventh revision, is given in parentheses.

^b Standardized mortality ratio, (observed/expected) × 100, not calculated for observed deaths less than 2.

^c 95 % confidence interval (two-sided test).

* $P < 0.05$.

5). Three of these deaths were from cancer of the tongue, two each from cancer of the lip and pharynx, and one from cancer of the buccal cavity.

Ninety-four deaths were due to cancers of the digestive organs and peritoneum (with 90.2 expected) (table 4). None of the site-specific cancers in this grouping was in excess. Of eight deaths from cancer of the liver, seven occurred among employees of tannery B (with 6.9 expected). All seven of these deaths occurred after a latency period of 15 years, and four of the seven deaths after 10 years of employment (with 2.7 expected) (table 5). Three of the deaths from liver cancer were among those employed in the tannery of tannery B, a finding which was statistically significant (SMR 720, 95 % CI 126–1 361). However, two of these deaths occurred among employees with less than one month of employment at the tannery.

Of the 40 deaths from genitourinary cancers (with 50.0 expected) (table 4), eight were due to cancer of the kidney (with 8.4 expected) and five were due to cancer of the bladder (with 6.8 expected). Seven of the eight kidney cancer deaths occurred after a period of 15 years of latency (with 5.6 expected). Four of these occurred after only one year of employment (table 5). Two deaths from cancer of the kidney occurred among employees of the beamhouse of tannery B (with 0.9 expected). Of the five deaths from cancer of the bladder, four occurred among employees of tannery B (with 4.1 expected) (table 4), and two of these deaths occurred among those employed in the retan, color, and fat-liquoring department (with 1.0 expected).

Mortality from diseases of the lymphatic and hemopoietic system was lower than expected for both tanneries (table 4). Within this category, deaths from both leukemia and aleukemia and from malignant lymphomas were below those expected.

One death resulted from cancer of the nasal cavity (with 0.4 expected) in an employee with more than 18 years' experience in the finishing department of tannery B.

Alcoholism and cirrhosis of the liver

Significant excesses of mortality from alcoholism (11 deaths, SMR 192, 95 % CI 101–344) and cirrhosis of the liver (45 deaths, SMR 150, 95 % CI 110–201) were observed among workers in tannery B, but not in tannery A (table 3). These statistically significant excess risks persisted when state rates were used as the comparison population. The majority (73 %) of the deaths from cirrhosis occurred among those employed less than one year at the tannery. Nine of the 45 deaths from cirrhosis occurred among employees of the beamhouse of tannery B (SMR 138, 95 % CI 62–203). Death certificate examination indicated that five of these nine deaths listed chronic alcoholism as a contributory cause.

Accidents

The excess of accidental deaths was of borderline statistical significance in tannery A (SMR 128, 95 %

CI 100–163) but slightly less than expected in tannery B (SMR 92, 95 % CI 73–115) (table 3). Of the 65 accidental deaths among the employees of tannery A, only 23 (with 22.2 expected) resulted from causes other than motor vehicle accidents, and only one (burned by flash fire) resulted from employment at the tannery. Most of the accidental deaths occurred among those employed in the beamhouse of tannery A (24 cases, SMR 228, 95 % CI 146–394). However, only eight (with 4.7 expected) of these deaths resulted from causes other than transportation, and none occurred at the tannery. Only 6 of the 24 deaths occurred within one year of last employment at the tannery.

Suicide

Deaths from suicide were significantly elevated over those expected for employees of tannery B (42 cases, SMR 171, 95 % CI 123–232) (table 3). Half of the tanners who died from suicide worked at the tannery for less than one year and committed suicide, on the average, 8.5 years after termination of employment. Only 3 of the 42 suicides occurred within one year of last employment at the tannery.

Discussion

The major findings of this study suggest, in general, that leather tanners and finishers are not at an increased risk for those causes of death that were of a priori concern, when their mortality experience was compared to that of either the US population or the population of the state in which the tanneries were located. These results seem to corroborate the only other mortality investigation focused *specifically* on employees of the leather tanning and finishing industry (30). This other study, however, was limited by small numbers (N = 833).

The outcomes of a priori concern in our investigation of tanners and finishers included cirrhosis of the liver, cancers of the liver, kidney, lung, bladder, nasal cavity, buccal cavity and pharynx, and larynx, and lymphoma. The concern for these diseases was based on adverse health effects previously reported by others for the leather and leather manufacturing products industry (as cited later) and chemicals known to have been used in the tannery environment.

Studies of employees from the broader category of the leather and leather manufacturing products indus-

Table 5. Mortality experience for selected causes of cancer by cumulative years of employment and 15-year latency interval since first employment among workers of two leather tanneries, 1940–1982^a. (O = observed number deaths)

Cause of death ^b	Cumulative years of employment											
	< 1			1–9			≥ 10			Total 15 years + latency		
	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d
All cancers (140–205)	111	84	70–102	58	101	77–131	72	75*	59–94	241	84*	74–96
Buccal cavity and pharynx (140–148)	3	79	20–215	3	187	48–510	2	71	12–236	8	97	42–191
Digestive organs and peritoneum (150–159)	31	90	61–128	21	135	84–207	31	114	77–162	83	103	82–128
Liver (155–156A)	2	66	11–213	1	.	.	4	148	47–357	7	96	39–199
Respiratory system (160–164)	31	77	52–109	15	89	50–146	9	33*	15–63	55	66*	50–86
Trachea, bronchus, lung (162–163)	30	78	53–112	15	93	52–154	7	27*	11–57	52	65*	49–85
Genitourinary tract (171–182)	17	94	55–151	5	60	19–140	12	75	39–131	34	80	55–111
Kidney (180)	4	141	45–345	1	.	.	2	97	16–315	7	114	46–235
Bladder (181)	3	100	26–273	—	.	.	1	.	.	4	51	14–130
Other and unspecified (190–199)	15	100	56–165	5	90	29–208	7	72	29–149	27	87	57–125
Lymphatic and hematopoietic (200–205)	9	82	37–156	5	103	33–240	8	104	45–205	22	93	58–141
Leukemia and aleukemia (204)	2	45	5–168	2	100	11–361	6	170	63–373	10	101	48–186
Lymphoma (200–203, 205)	7	105	42–219	3	105	21–305	2	48	5–173	12	87	45–153

^a Based upon United States mortality rates.

^b The code of the International Classification of Diseases, seventh revision, is given in parentheses.

^c Standardized mortality ratio, (observed/expected) × 100, not calculated for observed deaths less than 2.

^d 95 % confidence interval (two-sided test).

* P < 0.05.

Table 6. Mortality experience for selected causes by department among employees of two leather tanneries, 1940–1982.^a (O = observed number of deaths)

Causes of death ^b	Beamhouse			Tanyard			Retan, color, fat-liquor			Finishing			All other		
	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d	O	SMR ^c	95 % CI ^d
All cancers (140–205)	52	73*	55–96	36	74	52–103	54	72*	54–94	118	80*	66–96	71	82	64–103
Buccal cavity & pharynx (140–148)	2	82	14–275	.	.	.	2	79	23–264	1	.	.	4	156	49–371
Liver (155–156A)	1	.	.	3	230	59–628	2	105	18–348	1	.	.	2	87	15–287
Trachea, bronchus, lung (162–163)	16	68	42–119	5	36*	13–80	12	51*	26–90	24	70	45–105	144	59	33–100
Kidney (180)	2	126	21–413	1	.	.	1	.	.	3	102	26–273	2	103	18–348
Bladder (181)	.	.	.	.	.	.	2	96	16–315	3	89	23–247	1	.	.
Leukemia and aleukemia (204)	2	77	9–278	1	.	.	3	100	20–292	7	125	50–258	5	138	45–324
Lymphomas (200–203, 205)	3	83	17–243	1	.	.	1	.	.	7	92	37–190	2	45	5–164
Alcoholism (322)	3	138	35–371	1	.	.	2	88	15–287	3	121	31–327	3	182	48–510
Nervous system diseases (330–334)	16	54*	31–88	20	94	57–145	29	105	70–151	40	80	57–109	29	81	54–117
Circulatory system diseases (400–468)	119	74*	62–89	85	75*	59–91	132	79*	67–95	205	78*	68–90	199	103	90–119
Respiratory system diseases (470–527)	23	106	67–159	12	79	41–139	16	73	42–120	32	91	63–129	26	107	70–157
Cirrhosis of the liver (581)	11	111	55–199	3	50	13–136	10	88	42–163	21	122	76–187	17	166	97–267
Genitourinary system diseases (590–652)	1	.	.	7	80	33–168	3	61	16–170	4	76	24–186	6	104	38–229
Accidents (E800–E995)	44	148*	108–199	25	127	82–187	37	101	72–171	41	88	63–120	28	92	62–134
Suicide (E963, E970–979)	6	77	28–170	12	207*	107–361	17	165	97–267	15	97	54–160	14	150	82–253
Homicide (E964, E980–E985)	8	84	36–166	3	76	20–209	5	54	20–119	5	72	27–161	3	62	16–170
All causes ^e (001–998)	325	83*	75–94	219	81*	72–94	352	87*	87–97	539	81*	75–89	443	99	91–109

^a Ever worked in that department — Based upon United States mortality rates.

^b The code of the International Classification of Diseases, seventh revision, is given in parentheses.

^c Standardized mortality ratio, (observed/expected) × 100, not calculated for observed deaths less than 2.

^d 95 % confidence interval (two-sided test).

^e Includes unknown causes.

* P < 0.05.

try have shown varying results. Houton et al (18) reported increased risks for cancers of the bladder, buccal cavity and pharynx, and larynx among “operatives in the leather industry” when these workers were compared to clerical workers. In a series of case-referent analyses from the same population, DeCoufle (11) confirmed Houton’s findings and also observed an increased risk for malignant lymphomas compared to noncancer cases. Dubrow & Wegman (12) and Cole & Goldman (8) found statistically significant increased risks for bladder cancer and cirrhosis of the liver among “leather workers,” who included tanners, as well as among employees involved in the cutting, assembling and buffing of leather. Increased risk of kidney cancer has been reported among “leather workers” (2, 6, 26), as has risks from lung cancer (17, 22) and nasal cancer (10, 30).

Of particular interest were mortality risks associated with exposure to N-nitrosodimethylamine (NDMA). This chemical is an extremely potent carcinogen (11) that can be formed by the interaction of oxides of nitrogen and dimethylamine sulfate, a chemical used to accelerate dehairing in the tannery process. N-nitrosodimethylamine has been shown to cause cancer in a variety of organs, especially in the liver and kidney

(4, 16), in virtually every animal species in which it has been tested (28), although the doses used far exceeded the maximum exposures tolerated by man (24, 25). The carcinogenic risk to humans has yet to be established. Barnes & Magee (4) observed two cases of cirrhosis of the liver and liver damage among three men working in a research laboratory of a large industrial complex where N-nitrosodimethylamine had been used as a solvent.

In our study an elevated mortality risk was observed from cirrhosis of the liver (9 deaths, SMR 138, 95 % CI 62–203) and kidney cancer (2 deaths, SMR 222, 95 % CI 25–802) among the beamhouse employees of tannery B, where dimethylamine sulfate had been used to accelerate the dehairing process. A significantly increased risk for liver cancer (3 deaths, SMR 720, 95 % CI 126–1 361) was also observed in an adjacent (tanyard) department. The airborne levels of nitrosamines found ranged from 0.1–11 µg/m³, which, while very low, appear to be typical of a tannery that uses dimethylamine sulfate. However, higher levels have been observed in another tannery (32).

Of the nine deaths from cirrhosis of the liver in our study, five of the death certificates listed chronic alcoholism as a contributing cause, and, of the three

deaths due to liver cancer, two of the persons had been employed for less than one month at the tannery. Similarly, one of the two persons who died of kidney cancer had been employed for less than one month in the tannery. In addition, none of the deaths from nonmalignant diseases of the genitourinary system, including nephritis and nephrosis and kidney disease, were elevated. Therefore, the increased risks cited must be interpreted with caution.

In contradistinction to previous studies of workers in the leather and leather manufacturing products industry (10, 17, 22), this analysis did not find increased mortality from lung cancer or other nonmalignant respiratory diseases. In the earlier years (prior to World War II), US tanneries which tanned skins often used the two-bath tanning method in which hides were saturated with hexavalent chromium salts (potassium or sodium dichromate) and sulfuric acid and then removed manually and placed in a bath that reduced the dichromate to trivalent chromium sulfate. Exposures to hexavalent chromium compounds, some of which have been shown to be respiratory carcinogens in both animals and humans (20, 27), were probable. Several explanations may account for the apparent discordance between our results and those of the previous studies. First, since the early 1940s, most chrome tanneries in the United States have switched to the one-bath tanning method in which hexavalent chromium had already been reduced to trivalent chromium. Since fewer than 8 % of our cohort had been employed prior to 1940, worker exposure to hexavalent chromium was minimal. Second, the three previous studies referenced (10, 17, 22) included employees from the broader occupational category of the leather and leather manufacturing products industry. These employees may have been exposed to respiratory carcinogens not normally present in the tannery environment. Third, although the tobacco smoking habits of our cohort were unknown, the two tanneries under study had strict enforcement of anti-smoking rules and, therefore, employees probably did not smoke more than the comparison population. The only study of leather workers which has taken smoking status into account (40) also observed a lower than expected risk from lung cancer and other respiratory diseases among tannery workers.

Cancer of the bladder was of concern because of the use of some dyestuffs derived from benzidine and beta-naphthylamine in the dyeing of the chrome leather. Benzidine and beta-naphthylamine are dye intermediates which have been shown to be human bladder carcinogens (7, 19, 33). One of the two tanneries in our study, tannery B, showed detectable concentrations of benzidine in bulk dyes in the dye room. Of the four bladder cancer deaths that occurred in this tannery, two of the employees that died (with 1.0 expected) had once worked in the dye room. However, neither employee had worked for longer than two months at

the tannery and, due to small numbers, the results could have been due to chance.

In the finishing department of tannery B, there was one death due to squamous cell carcinoma of the nasal cavity. Cancer of the nasal cavity is rare. The annual incidence for white males is approximately eight in one million in the United States, about one-half of these cases being fatal within five years. Sixty percent of the fatal cases of nasal cancer are squamous cell carcinomas. Both formaldehyde exposure and leather dust have been linked with squamous cell carcinoma of the nasal cavity in rodents (3, 36) although the findings in human epidemiologic studies are still unclear (42). In the finishing department of tannery B, formaldehyde was used as a leather preservative and as a protein fixer on glazed leather, and leather dust originated from the buffing operation. The person with the single fatal case of squamous cell carcinoma of the nasal cavity in our study had worked in the finishing department for more than 18 years and died 55 years after initial employment, an induction-latency period consistent with occupational nasal carcinoma. The observation of nasal cancer among leather tanners was also recently reported in England (1 observed versus 0.21 expected) (30).

Deaths from accidental causes were found to be significantly elevated among employees of tannery A (SMR 128, 95 % CI 100–163), especially among those who had worked in the beamhouse. This finding was not unexpected since tanneries traditionally rank high in accidental injuries among all industries surveyed (39). However, only one accidental death occurred in this tannery. Almost all of the other accidental deaths resulted from fatal car or motorcycle accidents, accidental falls at home, or drownings. This result is consistent with data from the Bureau of Labor Statistics, which showed that, of 10 309 employment compensation claims filed during the years 1976–1983 for injuries in SIC 311, only four were for fatalities (37).

Our study had several limitations which should be noted. First, although our environmental surveys, conducted during 1979 and 1980, at the two tanneries had found all exposure levels to be below OSHA standards, except for formaldehyde, historic environmental measurements had never been conducted at either tannery. Because detailed information concerning past environmental exposures was not available, we defined exposures by classifying workers according to (i) the duration of their employment, (ii) the length of time interval since their first employment (latency), and (iii) their assignments to various departments. These are crude surrogate measures of actual exposure. Had we been able to identify more precisely those members of the cohort with the heaviest cumulative exposures, we might have been able to define more precisely the effects of such exposures on mortality. Second, mortality is not always an adequate indicator of potential health risks associated with employment,

particularly for those diseases such as bladder cancer which are readily treatable (35). Morbidity, which may be a better measurement of potential health risk in some cases, was beyond the scope of the present study. Third, ascertainment of vital status was only 95 % complete. While this percentage of follow-up is well within the range generally considered acceptable for cohort mortality studies, the 5 % deficit may have had the effect of inflating person-years at risk and thus lowering the SMR values. In addition, death certificates were not recorded for 50 (3.2 %) of the 1 582 known deaths. This occurrence had the effect of lowering the cause-specific SMR values by an additional 3.2 %, on the average. Fourth, although there is no particular reason to assume so, there is always the possibility that the personnel records may have been incomplete. Finally, the statistical power of this study to detect increases in mortality for diseases of a priori interest varied widely according to the background frequency of each condition (5), as shown by the confidence intervals.

In summary, although this study revealed some elevated risks for certain causes of death among tannery workers, no significantly increased risks were noted for any cause of death thought a priori to be occupationally related. Several limitations of this study, however, are discussed which may have accounted for our negative findings. Considering the limitations of this study, it would be improper to conclude that employment in the leather, tanning, and finishing industry presents no occupational health risks.

Acknowledgments

The authors wish to thank Ms E Dodd, Ms P Bischak, Ms C Battaglia and their colleagues for clerical support; Dr M Fingerhut for her helpful comments on the manuscript; and Ms R McGrath, Ms K Masterson and Ms J Nelson for assistance in preparation of the manuscript. We also gratefully acknowledge the guidance of Dr R Lollar, Technical Director of the Leather Industries of America.

References

1. Acheson ED, Cawdell RH, Jolles B. Nasal cancer in the Northamptonshire boot and shoe industry. *Br Med J* 1 (1970) 385—393.
2. Acheson ED, Pippard EC. Kidney cancer among leather workers. *Lancet* 1 (1984) 563.
3. Albert RF, Sellakumar AR, Lakin S, Kushner M, Nelson N, Snyder CA. Gaseous formaldehyde and hydrogen chloride induction of nasal cancer in the rat. *J Natl Cancer Inst* 68 (1982) 597—603.
4. Barnes JM, Magee PN. Some toxic properties of dimethylnitrosamine. *Br J Ind Med* 11 (1954) 167—174.
5. Beaumont J, Breslow N. Power considerations in epidemiologic studies of vinyl chloride workers. *Am J Epidemiol* 114 (1981) 725—734.
6. Cartwright RA, Bayko RW. Kidney cancer among leather workers. *Lancet* 1 (1984) 850.
7. Case RAM, Hosker ME, McDonald DB, Pearson JT. Tumors of the urinary bladder in workmen engaged in the manufacture and use of certain dyestuff intermediates in the British chemical industry. *Br J Ind Med* 11 (1954) 75—104.
8. Cole P, Goldman MB. In: Fraumeni JF Jr, ed. *Persons at high risk of cancer*. Academic Press, New York, NY 1975, pp 167—184.
9. Cole P, Hoover, Friedell G. Occupation and cancer of the lower urinary tract. *Cancer* 29 (1972) 1250—1260.
10. DeCoufle P. Cancer risks associated with employment in the leather and leather products industry. *Arch Environ Health* 38 (1979) 33—37.
11. Department of Labor, Occupational Safety and Health Administration. *Fed Regist* 39 (1974) 3756—3760.
12. Dubrow R, Wegman DH. Occupational characteristics of cancer victims in Massachusetts, 1971—1973. US Government Printing Office, Washington, DC 1984. (DHHS (NIOSH) publication no 84—109).
13. Fajen JM. In-depth industrial hygiene report of the SB Foot Tanning Company, Red Wing, Minnesota. National Institute for Occupational Safety and Health, Cincinnati, OH 1981. (Report no 106.10).
14. Fajen JM. In-depth industrial hygiene report of the AF Gallun and Sons Corporation, Milwaukee, Wisconsin. National Institute for Occupational Safety and Health, Cincinnati, OH 1981. (Report no 106.12).
15. Fajen JM, Fine DH, Rounbehler DP, Walker EA, Griciute L, Castegnaro M, Borzsonyi M. N-nitrosamines in the factory environment. In: Walker EA, Griciute L, Castegnaro M, Borzsonyi M, ed. *N-nitroso compounds: Analysis, formation and occurrence*. International Agency for Research on Cancer, Lyon 1980, pp 517—530.
16. Freund HA. Clinical manifestation and studies in parenchymatous hepatitis. *Ann Intern Med* 10 (1937) 1144—1155.
17. Garabrandt DH, Wegman DH. Cancer mortality among shoe and leather workers in Massachusetts. *Am J Ind Med* 5 (1984) 303—314.
18. Houton L, Bross ID, Viadana E, Decoufle P, Stanislawczyk K. A retrospective survey of cancer in relation to occupation. US Department of Health, Education and Welfare, Cincinnati, OH 1977. (DHEW (NIOSH) publication no 77—178).
19. Hueper WC. *Occupational and environmental cancer of the urinary system*. Yale University Press, New Haven, CT 1969, pp 118—141.
20. International Agency for Research on Cancer. Some metals and metallic compounds. Lyon 1980. (IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans, volume 23).
21. International Agency for Research on Cancer. Wood, leather, and some associated industries. Lyon 1981. (IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans, volume 25).
22. Kennaway EL, Kennaway NM. A further study of the incidence of cancer of the lung and larynx. *Br J Cancer* 1 (1947) 260—298.
23. Lollar RM. Are carcinogens a chronic health hazard in the tannery workplace? *J Am Leather Chem Assoc* 75 (1980) 510—525.
24. Magee PN, Barnes JM. Carcinogenic nitroso compounds. *Adv Cancer Res* 10 (1967) 163—246.
25. Magee PN, Montesano R, Preussman R. N-nitroso compounds and regulated carcinogens. In: Searle CE, ed. *Chemical carcinogens*. American Cancer Society, Washington, DC 1977, p 491. (American Cancer Society monograph no 173).
26. Malaker HR, Malaker BK, McLaughlin JK, Blot WJ. Kidney cancer among leather workers. *Lancet* 1 (1984) 56.
27. National Institute for Occupational Safety and Health. *Criteria for a Recommended Standard — Occupational*

- Exposure to Chromium (VI). Cinicinnati, OH 1975.
28. National Institute for Occupational Safety and Health. Registry of toxic effects of chemical substances. Volumes 1 & 2. Cincinnati, OH 1983.
29. New England Tanners Club. Leather facts. Peabody, MA 1977.
30. Pippard EC, Acheson ED, Winter PD. Mortality of tanners. *Br J Ind Med* 42 (1985) 285—287.
31. Rothman KJ, Boice JD. Epidemiologic analysis with a programmable calculator. US Government Printing Office, Washington, DC 1979. (NIH publication no 79—1649).
32. Rounbehler DP, Krull JS, Goff EU, Mills KM, Morrison J, Edwards GS, Fine DH, Fajen JM, Carson GA. Exposure to N-nitrosodimethylamine in a leather tannery. *Food Cosmet Toxicol* 17 (1979) 487—491.
33. Scott TS. The incidence of bladder tumors in a dyestuffs factory. *Br J Ind Med* 9 (1952) 127—136.
34. Stampfer MJ, Willett WC, Speizer FE, Dysert DC, Lipnick R, Rosner B, Hennekens CH. Test of the National Death Index. *Am J Epidemiol* 119 (1984) 837—839.
35. Stern FB, Murthy LI, Beaumont JJ, Schulte PA, Halperin WE. Notification and risk assessment for bladder cancer of a cohort exposed to aromatic amines: III Mortality among workers exposed to aromatic amines in the last beta-naphthylamine manufacturing facility in the United States. *J Occup Med* 27 (1985) 495—500.
36. Swenberg JA, Kerns WD, Mitchell RI, Gralla EJ, Pavkov KL. Induction of squamous cell carcinoma of the rat nasal cavity by inhalation exposure to formaldehyde vapor. *Cancer Res* 40 (1980) 3398—3401.
37. United States Department of Commerce. Supplementary data system, microdata files, Bureau of Labor Statistics 1976—1984. Washington, DC 1984.
38. United States Department of Commerce, Bureau of the Census. Preliminary report industry series, 1982. Washington, DC 1984 (Census of manufacturers MC 82-I-31A-1(P)).
39. United States Department of Labor, Bureau of Labor Statistics. Occupational injuries and illnesses in the United States by industry. Washington, DC 1984. (1982 bulletin 2196)
40. Walrath J, Rogot E, Murray J, Blair A. Mortality patterns among US veterans by industry and smoking status. US Government Printing Office, Washington, DC 1985. (DHHS, PHS, NIH publication no 85—2747).
41. Waxweiler RJ, Beaumont JJ, Henry JA, Brown DP, Robinson CF, Ness GO, Wagoner JK, Lemen RA. A modified life-table analysis system for cohort studies. *J Occup Med* 25 (1983) 115—124.
42. _____. Report on the consensus workshop on formaldehyde. *Environ Health Perspect* 58 (1984) 323—381.
43. _____. Standard industrial classification manual. US Government Printing Office, Washington, DC 1972. (Stock no 041-001-00066-6).

Received for publication: 25 March 1986