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Mortality Among Chrome Leather Tannery Workers: An Update

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Background *Employees engaged in the tanning and finishing of leather are potentially exposed to numerous carcinogens.*
Methods *A previous mortality study among 9,352 workers from two chrome tanneries has been updated with the addition of 11 years of vital status and work history follow-up and 1,153 new deaths. Ninety-two different causes of death were analyzed using a modified life-table approach. Death rates from both the United States and the states in which the tanneries were located were used as the comparison populations in calculating cause-specific standardized mortality ratios (SMRs).*
Results *The mortality risks from all causes and from all cancers were lower than the expected for the combined cohort. Analyzing the two tanneries separately, no a priori cause of death (i.e., cancer of the lung, pancreas, bladder, kidney, testes, nasal cavity, lymphoma, or soft-tissue sarcoma) was shown to be significantly elevated. An exception was lung cancer at one tannery when state death rates were used ($SMR = 130$, $P < 0.01$). Analyzing by duration of employment, no significant trend in any cause of death at either tannery was revealed.*
Conclusions *Some studies have shown elevated risks for various site-specific causes of cancer; however, sites in excess are not consistent between studies. The differences may have been due to distinct processes used by the tanneries resulting in varying levels, as well as different types, of exposures.* Am. J. Ind. Med. 44:197–206, 2003.
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BACKGROUND

In 1987, the results of a retrospective cohort mortality study of 9,365 leather tannery workers employed in two plants was reported [Stern et al., 1987]. The purpose of that study was to determine whether employees engaged in leather tanning and finishing (Standard Industrial Classification (SIC) 311) were at greater risk of developing various types of cancer. Various reports had shown that employment in the leather and leather manufacturing industry, SIC 31 [SIC Manual, 1972] [which includes SIC 311] was associated with cancers of the lung, pancreas, bladder, kidney, testes, nasal cavity, lymphoma, and soft-tissue sarcoma [DeCoufle, 1979; NIOSH, 1980; Garabrandt and Wegman, 1984; Malker et al., 1984; Edling et al., 1986; Levin et al., 1987; Seniori et al., 1989; Bonassi et al., 1990; Calvert et al., 1990; Chen, 1990; Marshall et al., 1990; Seniori et al., 1990; Comba et al., 1992; Mikoczy et al., 1994; Battista et al., 1995; Makela, 1996]. The results of our initial study showed no statistically significant elevated mortality risks for any of these cancers. However, statistically significant excess risks were observed due to injuries, cirrhosis of the liver, alcoholism, and suicide.

In this updated report, 11 years of vital status and work history follow-up (1983–1993) were added and new analyses conducted to determine whether statistically significant excess risks of mortality would now be detectable. Results from published epidemiologic studies of the leather tannery industry are also discussed.

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SUBJECTS AND METHODS

A detailed description of the study populations, the manufacturing processes of the two leather tanneries, and the various levels of exposures at the facilities studied were presented in the original report [Stern et al., 1987]. Briefly, the cohort consisted of all production workers employed for any length of time at either tannery A, in Red Wing, Minnesota, between 1 January 1940 and 11 June 1979 or at tannery B, in Milwaukee, Wisconsin, between 1 January 1940 and 1 May 1980.

Personnel records, which included demographic and work history information, were obtained from both tanneries. The information included name, social security number, gender, race, date of birth, date of hire, date of separation, and specific work history data including departments worked and the time spent in each department. The majority of the workers spent most of their time in the same department with little cross over into other departments.

Both tanneries used basic chromic sulfate as the main ingredient to produce soft, thin leather for use in the manufacture of personal leather goods such as shoes, handbags, gloves, etc. (~85% of all leather in the United States is chromed tanned).

In the original study, the vital status of the cohort was determined as of 31 December 1982. This update extends follow-up through 31 December 1993. Vital status follow-up was accomplished by searching the records maintained by the Social Security Administration and by the National Center for Health Statistics (NCHS). NCHS has created a computerized file, known as the National Death Index (NDI), which contains death information, including underlying and contributory causes of death, on all deceased individuals in the United States since 1979. Our updated follow-up started after 1982 therefore, all records of individuals not known to be deceased as of 31 December 1982 were sent to NCHS to be processed through the NDI file. For all those determined to be deceased, underlying as well as contributory causes of death were obtained and added to our file. Those lost to follow-up were considered alive up to the date last observed and their person-years at risk were accumulated to that date. Those who died after 31 December 1993 were considered alive for purposes of these analyses.

Work histories for persons employed at the time of the initial data collection (1979 and 1980) were updated to 31 December 1993 by going to the individual tanneries and obtaining their most current work records. Tannery B had closed its tanning operation at the beginning of July, 1993 and since that time had been importing tanned leather for finishing and distribution only; therefore, work histories for tannery B workers stopped at the end of June, 1993. Tannery A was still in operation and work histories through December 1993 were coded. Duration of employment was measured from date of first employment and was used in the analysis as a surrogate for cumulative exposure since the only environmental monitoring data available were those from surveys conducted by NIOSH in 1979–1980 at the two tanneries [Fajen et al., 1981a,b]. Since processes at the two plants had not varied over time according to company officials, the exposures measured were thought to be fairly indicative of prior years. Three categories for analysis by duration of employment were determined a priori: less than 1 year, 1–15 years, and greater than 15 years to obtain short, medium, and long-term workers. Company officials stated that turnover during the first year was common. Observed and expected numbers of deaths were also stratified according to ''ever having been employed'' in particular departments of the tannery. The departments were grouped according to process descriptions and exposures as presented in the earlier study [Stern et al., 1987]. The five department groups were: (a) beamhouse; (b) tanyard; (c) retan, color, and fat-liquor; (d) finishing; and (e) all others (e.g., packaging, shipping, office, quality control). Each department-specific analysis included everyone who ever worked in that department (only a few employees had worked in more than one department). Potential for exposures depended upon the department (area) in which the employee worked, although it was realized that overlapping of exposures between departments could possibly occur.

A modified life-table analysis system [Steenland et al., 1990] 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 the date last known to be alive (if the vital status was unknown), the date of death (if deceased), or 31 December 1993 (the last day of follow-up), whichever came earlier. The person-years at risk were subdivided by sex and race, and by five-year age groups and calendar-time periods. The person-years at risk were then multiplied by the appropriate sex-, race-, age-, and cause-specific mortality rates of the United States population to yield the number of expected deaths for 92 causes of death. Expected mortality was similarly computed with the use of the state death rates of Minnesota for tannery A and Wisconsin death rates for tannery B in order that variations in mortality patterns between states and national rates due to population composition and geographical location could be controlled for. However, we were only able to obtain state death rates for the years 1960 through 1993. Therefore, observed and expected mortality using state rates are shown for the years 1960–1993 only.

A standardized mortality ratio (SMR) value for each cause of death in each of the various analyses was computed by multiplying the ratio of the observed to the expected number of deaths by 100. A two-sided confidence limit (95%) for each SMR value was calculated assuming a Poisson distribution for the observed deaths [Rothman and Boice, 1979]. When the confidence interval (CI) did not include 100, the SMR value was considered to be statistically significant.

When observed deaths were fewer than 2, SMRs were not reported.

RESULTS

Cohort Description

The original cohort consisted of 9,365 workers. During the update, it was determined that 13 individuals had made application to one of the tanneries but never worked. They were deleted from the current analysis. The new total is 9,352 cohort members.

The results of the vital status ascertainment through 31 December 1993 are shown in Table I. An additional 1,153 cohort members had died since the previous study for a new total of 2,735 deaths; 29% of the study population had died by the end of the follow-up period versus 17% for the previous study. An additional 61,273 person-years at risk were added to the original study. There were 400 (4%) cohort members lost to follow-up.

Over 80% of the study population had been observed for a minimum of 18 years from the date of first employment to either the date last known to be alive, the date of death or study end date, whichever came first. Short-term workers comprised the majority of the cohort; approximately 66% had worked at the tanneries for less than 1 year, 24% between 1 and 15 years, and 10% for 15 years or longer.

Cause-Specific Mortality Using U.S. Death Rates

Selected cause-specific mortality for each tannery and for both tanneries combined using U.S. death rates for the years 1940–1993 is presented in Table II. Although 92 causes of death were examined in all analyses conducted, only those causes which were of a priori interest, causes where the risk was significantly elevated or lowered, as well as a few other selected causes are shown. None of the SMRs for causes of a priori concern, i.e., cancers of the lung, pancreas, bladder, kidney, testes, nasal cavity, lymphoma, or soft-tissue sarcoma was significantly elevated. In fact none of these SMRs was even elevated with the exception of the category, cancer of the connective and soft tissue, where four deaths were observed with three expected. Each of these four death certificates stated sarcoma was the cause of death. The cause-specific mortality for each of the two cohorts taken separately revealed statistically significant elevated risks for injuries among members from tannery A and statistically significant elevated risks for alcoholism, circulatory system diseases, cirrhosis of the liver, suicide, and all deaths combined among members from tannery B.

Cause Specific Mortality Comparing U.S. With State Death Rates

Examinations and comparisons of the results of analyzing each tannery separately using both US and state death rates for the years 1960–1993 are presented in Table III. For tannery A, the only SMR that was significantly elevated was injuries, regardless of whether U.S. or state death rates were used. For tannery B, when U.S. rates were used, SMRs for alcoholism, circulatory system diseases, cirrhosis of the liver, and suicide were statistically significantly elevated. When the Wisconsin state rates were used, these SMRs remained significantly elevated but, in addition, results for all causes combined, lung cancer, respiratory and digestive system diseases, and injuries became statistically significantly elevated.

Mortality by Years Employed

Results of mortality by duration of employment among members from tannery A and tannery B separately using state death rates as comparison are presented in Table IV. No specific cause of death showed a trend of increased risk with increasing employment. In fact, for many of the causes, there was a decreased risk with increasing employment at the tanneries. No SMR was statistically significantly elevated among those who worked 15 years or longer.

TABLE I. Vital Status of the Cohort Members of Two Tanneries by Sex and Race, 1940–1993

	Males		Females		
	White	Nonwhite	White	Nonwhite	Total cohort
Vital status	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
Alive	3,655 (63)	905 (73)	1,335 (70)	322 (85)	6,217 (66)
Deceased	1,984 (34)	259 (21)	452 (24)	40 (11)	2,735 (29)
Certificates obtained	1,923	248	422	36	2,629
Certificates not received	61	11	30	4	104
Lost to follow-up	190 (3)	81	113 (6)	16 (4)	400 (4)
Total cohort	5,829 (100)	1,245 (100)	1,900 (100)	378 (100)	9,352 (100)
Person-years at risk	168,164	26,972	61,860	8,503	265,499

TABLE II. Mortality Experience for Selected Causes for Two Tanneries and Total Using U.S. Death Rates as Comparison, 1940–1993

	Tannery A			Tannery B			Total		
Cause of death (ICDA-9)	**OBS/EXP**	**SMR**	**95% CI**	**OBS/EXP**	**SMR**	**95% CI**	**OBS/EXP**	**SMR**	**95% CI**
All causes (000–999)	939/1,055	89**	84–95	1,796/1,765	111**	106–116	2,734/2,680	102	98–106
All cancers (140–208)	181/226	80**	69–93	368/383	96	87–107	548/609	90*	83–98
Cancer of digestive organs (150–159)	55/61	90	68–117	104/97	107	88–130	158[a]/1,581	100	85–117
Cancer of pancreas (157)	11/12	96	48–172	16/18	87	50–141	27/30	90	59–131
Cancer of respiratory (160–165)	57/65	76*	57–98	126/114	111	92–132	183/189	97	83–112
Cancer of nasal cavity (160)	0			1			1		
Cancer of larynx (161)	3/3	103	21–300	5/4	119	38–277	8/7	112	48–221
Cancer of lung (162)	54/71	76*	57–99	119/108	110	91–132	173/180	96	83–112
Cancer of connective and soft tissue (171)	1			3/2	152	31–445	4/3	133	36–340
Cancer of testis (186)	0			0			0		
Cancer of kidney (189.0, 189.2)	5/6	93	30–217	7/8	89	36–183	12/13	91	47–158
Cancer of bladder (188, 189.3–189.9)	2/6	30	3–108	7/8	90	36–184	9/14	62	28–118
Cancer of hematopoietic tissue (200–208)	14/21	67	36–112	23/33	68	43–103	37/54	68*	48–94
Other neoplasms (202–203)	4/7	57	16–147	10/12	78	37–143	14/20	70	38–117
Leukemia and aleukemia (204–208)	6/9	68	25–148	10/12	75	133–281	16/22	72	41–118
Alcoholism (303)	2/3	60	7–217	22/8	286**	179–433	24/11	218**	140–324
Circulatory system (390–459)	344/414	83**	74–92	613/557	110*	101–119	957/976	98	92–105
Respiratory system (460–519)	77/74	104	82–130	109/105	104	86–126	186/153	104	90–120
Digestive system (520–579)	38/46	83	59–114	89/78	114	92–140	127/123	103	85–122
Cirrhosis of liver (571)	11/21	52*	26–93	59/40	151**	115–194	70/60	116	90–146
Genitourinary system (580–629)	13/16	83	44–142	24/27	90	58–134	37/42	87	61–120
Injuries (E800–848)	80/63	127*	101–158	109/101	108	83–130	189/164	115	99–133
Suicide (E950–959)	26/22	117	77–172	51/31	162**	113–174	77/53	144**	113–180

[a]One tannery worker had worked at both tanneries. This worker died of cancer of the digestive organs and is included in the results of both tanneries.

*$P < 0.05$.

**$P < 0.01$.

TABLE III. Mortality for Selected Causes for Two Separate Tanneries. Comparison Using U.S. and State Death Rates, 1960–1993

	Tannery A				Tannery B			
Cause of death (ICDA-9)	**OBS**	**SMR (US)**	**SMR (MN)**	**95% CI (MN)**	**OBS**	**SMR (US)**	**SMR (WI)**	**95% CI (WI)**
All causes (000–999)	834	93*	105	98–112	1,630	113**	124**	118–130
All cancers (140–208)	162	80**	90	77–105	348	99	103	92–143
Ca. of digestive (150–159)	47	90	93	68–123	94	108	108	87–132
Ca. of pancreas (157)	10	98	99	48–183	16	93	94	54–152
Ca. of respiratory (160–165)	56	80	107	81–139	121	111	130**	108–156
Ca. of larynx (161)	3	118	163	34–478	4	103	128	35–327
Ca. of lung (162)	53	79	106	80–139	116	112	131**	108–157
Ca. of connective/soft tissue (171)	1	—	—	—	2	108	100	12–362
Ca. of kidney (189.0, 189.2)	4	83	77	21–197	7	96	83	33–170
Ca. of bladder (188, 189.3–189.9)	1	—	—	—	7	100	102	41–209
Lymphatic/hematopoietic (200–208)	13	70	64	34–109	23	75	72	46–108
Leukemia/aleukemia (204–208)	5	65	60	20–141	10	84	81	39–148
Alcoholism (303)	1	—	—	—	21	301*	267**	165–408
Circulatory system (390–459)	310	88*	101	90–113	549	111	119**	110–130
Respiratory system (460–519)	71	106	125	98–158	102	91	123*	101–150
Digestive system (520–579)	35	93	120	83–167	80	116	142**	113–177
Cirrhosis of liver (571)	10	55	81	39–148	56	156**	212**	160–276
Genitourinary system (580–629)	12	98	129	66–225	19	87	102	62–160
Injuries (E800–848)	66	140*	146**	113–185	93	115	134**	108–164
Suicide (E950–959)	22	123	135	86–203	43	162**	164**	118–220

*$P < 0.05$.
**$P < 0.01$.

Mortality by Department

Results of mortality by department for both tanneries combined are shown in Table V. Some elevated risks were seen among tanners who worked in the beamhouse with two of those results, deaths due to alcoholism and deaths due to injuries, reaching statistical significance. There were statistically significant deficits of circulatory system deaths among tanyard workers, and cancers among workers in the tanyard and finishing departments.

Comparison to Previous Study

A comparison of the results of the earlier study [Stern et al., 1987] and the updated study was conducted. Only those causes of death that had a statistically significant excess risk in the previous study were found to have statistically significant results in the updated study, and the SMRs between the studies were remarkably similar (see Table III in previous study and Table II in the present study). For tannery A, the only significant risk was injuries; SMR = 128 (CI: 101–163) in the previous study and SMR = 127 (CI: 101–158) in the current study. For tannery B, the three significant risks were alcoholism, SMR = 192 vs. 286; cirrhosis of the liver, SMR = 150 vs. 151; and suicide, SMR = 171 vs. 162, for the previous and current studies, respectively. A comparison of the results between the two studies is presented in Table VI.

DISCUSSION

The major finding of this updated study of the mortality experience of employees from two leather tanneries, in which the follow-up period was increased by 11 years, was the lack of significantly elevated risk for those causes of death that were of a priori interest. These included cancers of the lung, bladder, nasal cavity, pancreas, kidney, and testes, as well as lymphoma and soft-tissue sarcoma. In fact, the SMRs for all these causes of death were lower than expected in the follow-up study, with the exception of cancers of the connective and soft tissue, and changed minimally from the original study even though the follow-up period was as long as 53 years (1940–1993). This time frame would have been sufficient for diseases with long latency periods to develop among workers first employed in the earlier years. Furthermore, none of these causes of death showed any trend toward elevated risk by duration of years employed.

Tannery workers in general have been known from previous studies to have the potential for exposure to numerous known or suspected occupational carcinogens, including, among others, hexavalent chromium salts, arsenic, organic solvents (e.g., benzene and formaldehyde),

TABLE IV. Mortality for Selected Causes for Two Separate Tanneries by Years of Employment Using State Death Rates, 1960–1993

	Tannery A								Tannery B							
	Years of employment								Years of employment							
	<1		1–15		15+		Total		<1		1–15		15+		Total	
Cause of death (ICDA-9)	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**	**OBS**	**SMR**
All causes (000–999)	353	121**	277	109	204	82**	834	105	1,048	139*	377	97	205	92	1,630	124**
All cancers (140–208)	66	95	62	106	34	64**	162	90	209	104	95	106	44	91	348	103
Ca. of digestive (150–159)	18	95	18	55	11	71	47	93	49	100	30	132*	15	107	94	108
Ca. of pancreas (157)	2	51	7	218*	1		10	99	10	100	4	91	2	97	16	94
Ca. of respiratory (160–165)	21	100	26	156*	9	62	56	107	78	135*	32	141*	11	87	121	130**
Ca. of larynx (161)	1		1		1		3	163	3	159	0		1		4	128
Ca. of lung (162)	20	100	25	156*	8	58	53	106	74	135*	32	143*	10	89	116	131**
Ca. of connective/soft tis. (171)	0		1		0		1		2	153	0		0		2	100
Ca. of kidney (189.0, 189.2)	2	96	1		1		4	77	4	76	2	99	1		7	83
Ca. of bladder (188, 189.3–189.9)	0		0		1		1		5	145	1		1		7	102
Lymph/hematopoietic (200–208)	5	62	4	89	4	77	13	64	13	68	6	74	4	87	23	72
Lympho/reticulo sarcoma (200)	0		2	160	0		2	74	0		1		0		1	
Leukemia/aleukemia (204–208)	2	62	1		2	83	5	60	5	68	2	31	3	139	10	81
Alcoholism (303)	1		0		0		1		15	259*	6	243*	0		21	267**
Circulatory system (390–459)	127	118	96	98	87	85	310	101	322	130**	137	115*	90	97	549	119*
Respiratory system (460–519)	27	147	27	150	17	84	71	125	65	148**	17	78	20	117	102	123*
Digestive system (520–579)	16	140	10	115	9	108	35	120	57	168*	18	131	5	65	80	142**
Cirrhosis of liver (571)	5	91	4	100	1		10	81	41	234**	12	190*	3	123	56	212**
Genitourinary sys (580–629)	4	137	2	68	6	174	12	129	9	89	5	106	5	133	19	102
Injuries (E800–848)	38	174**	23	149	5	61	66	146*	73	149**	18	122	2	36	93	134**
Suicide (E950–959)	14	163	6	107	2	76	22	135	38	197**	4	100	1		43	164**

*$P < 0.05$.
**$P < 0.01$.

TABLE V. Mortality Experience for Selected Causes for Two Tanneries Combined, by Department, 1940–1993, Using U.S. Rates

	Tannery Departments									
	Beamhouse		Tanyard		Retan, color, fat		Finishing		Other Dept.	
Cause of death (ICDA-9)	OBS	SMR	OBS	SMR	OBS	SMR	OBS	SMR	OBS	SMR
All causes (001–999)	539	100	361	91	621	99	1,050	95	703	105
All cancers (140–208)	106	94	61	74*	126	93	232	86*	141	95
Cancer of digestive organs (150–159)	33	106	19	84	38	106	68	102	39	98
Cancer of respiratory system (161–165)	43	110	18	67	45	94	71	94	49	105
Cancer of lung (162)	43	116	17	66	44	97	67	93	43	97
Cancer of connective and soft tissue (171)	1	—	0	—	2	297	1	—	0	—
Cancer of kidney (189.0, 189.2)	3	117	2	105	1	—	5	90	4	120
Cancer of bladder (188, 189.3–189.9)	0	—	0	—	2	58	7	120	1	—
Lymphatic and hematopoietic tissue (200–208)	6	60	5	66	8	64	22	91	9	67
Leukemia and aleukemia (204–208)	2	49	2	63	5	98	9	93	6	109
Alcoholism (303)	7	253*	1	—	8	252**	4	113	5	210
Circulatory system (390–459)	179	90	126	84*	206	90	371	94	264	104
Respiratory system (460–519)	45	124	28	103	38	91	77	102	48	108
Digestive system (520–579)	30	120	14	79	24	81	43	85	32	107
Cirrhosis of liver (571)	15	120	6	72	14	91	25	105	19	134
Genitourinary system (580–629)	7	80	4	63	8	84	15	85	13	125
Injuries (E800–848)	54	155**	34	133	48	107	54	90	43	108
Suicide (E950–959)	11	108	14	167	22	156	19	90	19	140

*$P < 0.05$.
**$P < 0.01$.

TABLE VI. Selected Results Between Previous and Updated Studies of Tannery Workers

	Previous study results (1940–1982)			Current study results (1940–1993)		
Cause of death (ICDA-9)	OBS	SMR	95% CI	OBS	SMR	95% CI
Tannery A: comparison using U.S. death rates						
All causes (000–999)	568	81*	84–88	939	89**	84–95
All cancers (140–208)	104	78*	64–95	181	80**	69–93
Circulatory system (390–459)	239	76*	67–87	344	83**	74–92
Cirrhosis of liver (571)	7	44*	18–92	11	52*	26–93
Injuries (E800–848)	65	128*	101–163	80	127*	101–158
Tannery B: comparison using U.S. death rates, 1940–1993						
All causes (000–999)	1,014	93	88–100	1,796	111**	106–116
All cancers (140–208)	178	80*	69–93	368	96	87–107
Circulatory system (390–459)	381	91	82–101	613	110*	101–119
Alcoholism (303)	11	192*	101–344	22	197**	133–281
Cirrhosis of liver (571)	45	150*	110–201	59	151**	115–194
Injuries (E800–848)	79	92	73–115	109	108	88–130
Suicide (E950–959)	42	171*	123–232	51	162**	113–174

*$P < 0.05$.
**$P < 0.01$.

N-nitrosodimethylamine derived from dimethylamine sulfate and used as an accelerator in the dehairing process, dimethylformamide, airborne leather dusts, benzidine-based azo dyes, and chlorophenols including pentachlorophenols [Fajen et al., 1981a,b; Linberg and Argen, 1988]. These exposures within the leather tanning industry have been suggested by some investigators to result in the development of a variety of site-specific cancers including lung, bladder, kidney, pancreatic, nasal, testicular, and soft tissue sarcoma.

Upon re-evaluation of the exposure data for this cohort, it was determined that the industrial hygiene data reported in the earlier article [Stern et al., 1987] provided an inaccurate characterization of the exposure potentials that were present at the two tanneries. Nevertheless, based on the surveys conducted at these two tanneries [Fajen et al., 1981a,b] and the fact that they used similar tanning processes, workers in this study were potentially exposed to detectable concentrations of chromium, formaldehyde, dimethyl amine, ammonia, hydrogen sulfide, formic and sulfuric acids, and various solvents including toluene, acetone, xylene, butyl cellusolve, and methyl isobutyl ketone.

A significant excess risk of lung cancer was observed among members from tannery B when Wisconsin rates were used as the comparison. This result did not occur when U.S. rates were used as the comparison or when results among members from tannery A were analyzed using either state or national rates. The process of tanning of leather and, therefore, the potential for occupational exposures, was similar at the two tanneries. Differences in mortality between the two tanneries, however, centered around an excess risk of alcoholism, cirrhosis of the liver, circulatory and respiratory system diseases which were all significantly elevated among members from tannery B whether U.S. or state rates were used but not elevated among members from tannery A. Information regarding smoking status or amount of cigarette smoking among members from tannery B were not available. However, an excess risk of respiratory and circulatory diseases is highly associated with smoking. Alcoholism and cirrhosis have also been shown to be correlated and both have been shown to be associated with cigarette smoking [Friedman et al., 1991; Klatsky and Armstrong, 1992]. Therefore, the excess of lung cancer among only members from tannery B might at least be partially explained by cigarette smoking. An excess of *lung cancer* has also been observed in two studies of tannery workers in Italy [Bonassi et al., 1990; Seniori et al., 1990] and in a case-control study in the United States (U.S.) [Garabrandt and Wegman, 1984], but these results were not supported by other studies [Pippard and Acheson, 1985; Mikoczy et al., 1994]. Chromium and arsenicals were mentioned as possible contributors to the lung cancer excess.

A study of the Chinese leather tanning industry showed a statistically significant excess morbidity from *bladder cancer* among tanners ever exposed to benzidine-based dyes, which increased with duration of exposure [Chen, 1990]. A similar result was reported by Seniori et al. [1989] in her own study of the Tuscan tanning industry and in her review of other studies among workers in leather finishing operations [Seniori et al., 1990]. In our mortality study, bladder cancer risk was not elevated. However, since bladder cancer survival is good (the U.S. 5-year survival rate was 84% for males diagnosed in 1987 [Kosary et al., 1995], a better estimate of the true risk of bladder cancer would require an analysis of incident cases rather than deaths.

An excess of kidney cancer among tannery workers has been suggested by two investigators [Malker et al., 1984; Seniori et al., 1989]; dyes and pigments were mentioned as possible causative factors. Although samples of benzidine-based dyes were found in the retan, color and fat-liquoring department of both tanneries, only one kidney cancer death was observed in this department. No excess kidney cancer mortality was noted for this study population overall and the SMR for kidney cancer was found to decrease with increasing duration of employment.

A threefold statistically significant excess in *pancreatic cancer* mortality was noted in a Swedish case-referent study [DeCoufle, 1979]; a 50% increase in pancreatic cancer was also noted in another study of three Swedish tanneries [Seniori et al., 1989; Mikoczy et al., 1994] and in a study of an Italian tannery [Seniori et al., 1989]. Despite the excess risk of pancreatic cancer, no specific environmental agent was identified and dietary factors were considered a possibility. Pancreatic cancer was not elevated in our study.

An excess risk of *sinonasal cancer* among leather tannery workers was observed in a case-control study in Italy; chromium, leather dust, and tannins were indicated as possible etiologic agents [Comba et al., 1992; Battista et al., 1995]. The mean latency period was 47 years. Although many of the cohort members in our study had a long latency period, we found only one case of nasal cancer. IARC reported [IARC, 1987] that there was no evidence of an increased risk of nasal cancer in the leather tanning and processing industry.

An excess risk of *testicular cancer* incidence was observed among leather tanners from the finishing department of one tannery; all three workers with testicular cancer had worked during the same time period and during the same shift and were exposed to dimethylformamide (DMF), a substance known to cause testicular damage [Levin et al., 1987; Calvert et al., 1990]. The study by Levin et al. [1987] led to a nested case-control study of a cluster of cancer cases in Fulton County, New York, where substantial leather tanning was being conducted. The authors found a statistically significant odds ratio of 7.2 for testicular cancer among leather tanners in this area [Marshall et al., 1990]. DMF was suggested as a possible cause of the excess. Only one death from testicular cancer was observed in our study. Air samples taken at these two tanneries in 1979–1980 were not analyzed for DMF; therefore, it is not known if these exposures existed or not.

A statistically significant 3½-fold risk for malignant lymphoma was observed in a case-control study by DeCoufle [1979], but this result has not been confirmed in other studies.

A significantly increased risk of soft tissue sarcoma, an extremely rare cancer accounting for only 1% of all fatal cancers, has been observed in at least two separate tannery studies; one in Italy (a mortality investigation) and one in Sweden (an incidence study). Both investigators suggested that chlorophenols, used in the pretanning operation of the beamhouse and in the tanning department, which have been associated with these malignancies, may have produced these tumors [Mikoczy et al., 1994]. We observed four deaths due to cancers of the connective and soft tissue, where three would have been expected. All four death certificates stated sarcoma as the cause of death. Two of the four sarcomas were among employees who worked in the tanyard and one was from an employee who worked in the beamhouse. Soft tissue sarcoma in epidemiologic mortality studies is complicated by nosologic coding rules that require that soft tissue sarcoma arising in a visceral organ must be coded in the International Classification of Diseases (ICD) category for that organ, rather than the ICD category for malignant diseases of connective tissue (ICD 171). This may have reduced the sensitivity of our study to detect an excess risk of soft tissue sarcoma.

There were statistically significant increased risks from alcoholism, cirrhosis of the liver, and suicide deaths among members of tannery B from our study. Alcoholism, cirrhosis of the liver, and suicide have been shown to be highly correlated [Rushing, 1969; Linberg and Argen, 1988; Borges et al., 1990; Makela, 1996]. Although we had no information on alcohol consumption among the members of this cohort, these excess risks were observed only in tannery B, and there was no trend observed with increased duration of employment. This suggests a non-occupational risk factor. It was also interesting to note that the increase in SMRs for these causes was greater among those employed at the tannery in earlier decades (1950s, 1960s) rather than in later decades (1970s, 1980s). Alcohol consumption may very well have been the contributing factor for the excess risk of cirrhosis of the liver and for the increased risk of suicide.

The injuries death rate was significantly increased in tannery A and elevated in tannery B using U.S. rates and significantly elevated in both tanneries when their respective state rates were used. However, as in the original study, only one death occurred due to an injury while at work. The remaining deaths were caused by vehicular accidents, falls at home or drowning.

In summary, this updated analysis has provided additional deaths, employment data, and increased latency to further assess possible elevated risks of death among workers from two leather tanneries. The results are very consistent with those of the original study and show no elevated risks for those causes of death that were of a priori interest. Although some other studies of tannery workers have shown elevated risks for various site-specific causes of cancer, the results from these other studies seem to vary and show somewhat inconsistent results. Some of the differences may have resulted from the different processes used which could have resulted in different and varying exposures. A cancer incidence study of these tannery workers also might help clarify exposure-cancer relationships, particularly for cancers with high survival rates.

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