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Mortality of chrome leather tannery workers and chemical exposures in tanneries

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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 dehauling 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

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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 | Concentrationa |
|-------------------------|---------------------|--------------------------------------|-------------------|---------------|
|                         |                     |                                      | Range b           | Mean c         |
| Beamhouse               |                      |                                      |                   |               |
| 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 3 | 0-2.0 | 1.3 |
|                         | (produced from dimethylamine sulfate) | N-nitrosodimethylamine 29 | 0-11 | 3.5 |
| Flesh                   | Remove excessive flesh, fat, and muscle | | | |
| Delime and bake         | Neutralize the high alkalinity of the limed hides with buffering salts (eg, ammonium sulfate or ammonium chloride) | Ammonia 2 | 9-30 | 19.5 |
|                         | | Sulfuric acid 6 | 0-0.24 | 0.12 |
| Pickle                  | Place the hide in an acid environment ready to accept the tanning material using a solution of sodium chloride and sulfuric acid | | | |
| Tanyard                 | | | | |
| 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) | 55 | 0.2-54 | 38.8 |
|                         | Total chrome (%) (bulk sample) | 5 | 1.5-3.8 | 2.7 |
| Wring                   | Remove excess moisture to ease splitting | | | |
| Split and shave         | Adjust thickness of the hide | | | |
| Retan, color, fat-liquoring | Add tanning agents such as vegetable and synthetic tannins to modify the physical properties of the leather | | | |
| Color                   | Color the leather using acid, metallic, basic, or direct dyes | Formic acid 19 | 1.3-6.7 | 3.0 |
|                         | | Benidine in bulk dyes 2 | 2.0-55 | 28.3 |
|                         | | Copper 2 | 0.0-0.0 | 0.0 |
| Fat-liquoring           | Lubricate the leather with animal oil to give it pliability and tensile strength | Cobalt 2 | 0.0-0.0 | 0.0 |
|                         | | Manganese 2 | 0.0-0.0 | 0.0 |
| Dry                     | Remove excess moisture | | | |
| Set out                 | Smooth and stretch the leather | | | |
| Finishing               | Mechanical and chemical operations that soften, smooth, and help preserve the leather | N-butyl acetate 27 | 0.0-0.0 | 0.0 |
| Condition, stake, buff, finish, plate, measure, grade | Butyl cellosolve 69 | 0.2-12 | 1.6 |
|                         | Methyl ethyl ketone 26 | 0.0-0.0 | 0.0 |
|                         | Methyl isobutyl ketone 83 | 0.3-51 | 6.5 |
|                         | Toluene 83 | 0.2-206 | 26.1 |
|                         | Xylene 83 | 0.0-48 | 15.1 |
|                         | Acetone 83 | 0.3-105 | 13.9 |
|                         | Formaldehyde 5 | 0.5-7 | 2.45 |
|                         | Airborne leather fibers 22 | 0.2-3.9 | 0.26 |
|                         | Copper 2 | 0.0-0.0 | 0.0 |
|                         | Cobalt 2 | 0.0-0.0 | 0.0 |
|                         | Manganese 2 | 0.0-0.0 | 0.0 |
|                         | Cadmium 2 | 0.0-0.0 | 0.0 |
|                         | Respirable dust 3 | 0.0-0.0 | 70 % |

All other (mainly maintenance and support)

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 1). 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-
expected 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 6).

### 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 | Total cohort | |
|               | Number | Percentage | Number | Percentage | Number | Percentage | Number | Percentage | Number | Percentage |
| Alive         | 4376  | 75     | 1037  | 82     | 1549  | 82     | 354    | 92     | 7316  | 78     |
| Deceased      | 1219  | 21     | 137   | 11     | 216   | 11     | 10     | 3      | 1582  | 17     |
| Death certificates obtained | 1184 | -      | 125   | -      | 213   | -      | 10     | -      | 1532  | -      |
| Death certificates outstanding | 35   | -      | 12    | -      | 3     | -      | 0      | -      | 50    | -      |
| Lost to follow-up | 232  | 4      | 84    | 7      | 132   | 7      | 19     | 5      | 467   | 5      |
| Total cohort  | 5827  | 100    | 1258  | 100    | 1897  | 100    | 383    | 100    | 9365  | 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 deathb | 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—79 | 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—999) e | 1582 | 89* 85—94 | 568 | 81* 84—88 | 1014 | 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) x 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               | Observed deaths | Tannery A | Tannery B | Tannery A | Tannery B |
|-----------------------------|-----------------|-----------|-----------|-----------|-----------|
|                             | Observed deaths | SMR<sup>b</sup> | SMR<sup>b</sup> | 95% CI<sup>c</sup> | Observed deaths | SMR<sup>b</sup> | SMR<sup>b</sup> | 95% CI<sup>c</sup> |
| All cancers (140—205)       | 99              | 78        | 88        | 72—107    | 177         | 84*       | 82        | 73—98      |
| Buccal cavity and pharynx   | 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<sup>a</sup>) | 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        | 96        | 27—253     |
| Other and unspecified (190—199) | 15              | 102       | 116       | 65—192    | 21          | 83        | 71        | 45—107     |
| Lymphatic and hematopoietic 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     |

<sup>a</sup> The code of the International Classification of Diseases, seventh revision, is given in parentheses.

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

<sup>c</sup> 95% confidence interval (two-sided test).

*<sup>*</sup> 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 B, a finding which was statistically significant (SMR 720, 95% CI 126—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 hematopoietic 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 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. | Cumulative years of employment | O | SMR<sup>c</sup> | 95 % CI<sub>c</sub> | O | SMR<sup>c</sup> | 95 % CI<sub>c</sub> | O | SMR<sup>c</sup> | 95 % CI<sub>c</sub> | Total 15 years + latency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All cancers (140—205) | < 1 | 111 | 84 | 70—102 | 58 | 101 | 77—131 | 72 | 75<sup>a</sup> | 59—94 | 241 | 84<sup>a</sup> | 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<sup>a</sup> | 15—63 | 55 | 66<sup>a</sup> | 50—86 |
| Trachea, bronchus, lung (162—163) | 30 | 78 | 53—112 | 15 | 93 | 52—154 | 7 | 27<sup>a</sup> | 11—57 | 52 | 65<sup>a</sup> | 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 | . | . | . | 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 |

<sup>a</sup> Based upon United States mortality rates.
<sup>b</sup> The code of the International Classification of Diseases, seventh revision, is given in parentheses.
<sup>c</sup> Standardized mortality ratio, (observed/expected) x 100, not calculated for observed deaths less than 2.
<sup>d</sup> 95 % confidence interval (two-sided test).
<sup>*</sup> P < 0.05.
Table 6. Mortality experience for selected causes by department among employees of two leather tanneries, 1940—1982.a

| Causes of deathb | Beamhouse | Tanyard | Retan, color, fat-liquor | Finishing | All other |
|------------------|-----------|---------|-------------------------|-----------|-----------|
|                   | O SMRc | 95% CI | O SMRc | 95% CI | O SMRc | 95% CI | O SMRc | 95% CI | O SMRc | 95% CI |
| All cancers (140—205) | 52 | 73% | 55—96 | 36 | 74 | 52—103 | 54 | 72% | 54—94 | 118 | 80% | 66—103 | 71 | 82% | 64—103 |
| Buccal cavity & pharynx (140—149) | 2 | 82% | 14—275 | 2 | 79 | 23—264 | 1 | . | . | 2 | 105 | 18—348 | 1 | . | . |
| 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 | . | . | 3 | 102 | 28—373 | 2 | 103 | 18—348 |
| Bladder (185) | 2 | 96 | 21—315 | 2 | 79 | 23—264 | 4 | 156 | 49—371 | 5 | 138 | 45—324 |
| Leukemia and aleukemia (204) | 2 | 77% | 9—278 | 3 | 100 | 20—292 | 7 | 125 | 50—256 | 5 | 138 | 45—324 |
| Lymphomas (200—203, 205) | 3 | 83 | 17—243 | 7 | 92 | 37—190 | 2 | 45 | 5—164 |
| Alcoholism (322) | 3 | 138 | 35—371 | 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% | 66—90 | 199 | 103 | 99—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—145 | 17 | 166 | 97—267 |
| Genitourinary system diseases (590—652) | 80 | 33% | 16—88 | 3 | 61 | 16—170 | 4 | 76 | 24—186 | 6 | 104 | 38—229 |
| Accidents (E800—E995) | 44 | 148 | 62—203 | 25 | 127 | 82—187 | 37 | 101 | 72—171 | 41 | 88 | 63—120 | 28 | 92 | 62—134 |
| Suicide (E963,E970—979) | 8 | 84 | 36—166 | 3 | 76 | 20—209 | 5 | 54 | 20—119 | 5 | 72 | 27—161 | 3 | 62 | 16—170 |
| All causes (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.

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—1361) 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.

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