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MORTALITY AMONG RUBBER WORKERS

I. WHITE MALE UNION EMPLOYEES IN AKRON, OHIO

RICHARD R. MONSON AND KENNETH K. NAKANO

Monson, R. R. (Dept. of Epidemiology, Harvard School of Public Health, 677 Huntington Ave., Boston, MA 02115) and K. K. Nakano. Mortality among rubber workers. I. White male union employees in Akron, Ohio. *Am J Epidemiol* 103:284–296, 1976.

Mortality among a cohort of 13,571 white male rubber workers in Akron, Ohio is described. Mortality from all causes was 82% of that expected on the basis of death rates for US white males. Excess deaths from cancer (observed/expected numbers;) in specific sites among workers in specific work areas include stomach: processing (18/9.9); large intestine: processing (14/10.5); lung: tire curing (20/12.4); bladder: all workers (48/39.5); brain: tire building (7/3.7); lymphatic: tire building (11/7.1); and leukemia: all workers (55/43.0). In general, excess cancer deaths occurred most often among men who started working between ages 35 and 44 and prior to 1935, who worked 25–34 years and were over age 74 at death, and who died after 1954.

Cancer, incidence of; occupational diseases; rubber workers

In 1954, an excess rate of tumors of the urinary bladder among workers in the rubber industry was reported (1). Since then a number of investigators have studied total and cause-specific mortality among rubber workers (2–6). While no evidence has been reported to suggest that overall mortality is increased among rubber workers, excesses of cancer of several other sites have been reported: salivary glands (4), stomach (3, 6), large intestine (3, 6, 7), gallbladder and bile ducts (4), lung (2, 5, 7), prostate (6), brain (2, 3, 5), lymphosarcoma (6, 7) and leukemia (5, 6).

In 1970 the six major United States rubber companies, after negotiation with the United Rubber, Cork, Linoleum and Plastic Workers of America, agreed to support studies of the health effects of the work environment. In this paper the mortality experience between January 1, 1940, and June 30, 1974, of 13,571 white male employees of one of these companies is reported. Also, for workers who died between 1925 and 1939, a proportional mortality analysis is presented.

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Abbreviation: SMR, standard mortality ratio.

From the Department of Epidemiology, Harvard School of Public Health, Boston, MA 02115.

Supported by a contract with the B. F. Goodrich Company and the United Rubber, Cork, Linoleum and Plastic Workers of America and by a center grant (5 P10 ES00002) from the National Institute of Environmental Health Sciences.

The authors are indebted to I. Mikelsons, L. Pape, and L. Taylor for technical assistance; to W. H. Veigel, Ohio Department of Health, for assistance in obtaining death certificates; to Marian Heid, National Institute for Occupational Health, for coding death certificates; to officials of the I.R.S. and S.S.A. for assistance with the follow-up of terminated employees; to officers of URW Local #5 for maintaining a valuable source of occupational histories; and to the members of the Occupational Health Committee of the United Rubber, Cork, Linoleum and Plastic Workers of America and the B. F. Goodrich Company for support of this study and concern for the health of the rubber worker.

METHODS

Definition of population. All members of the study population were employed by one company in Akron, Ohio, and were mem-

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bers of the same local union. The majority worked in a plant in which tires and other rubber products are manufactured. Smaller numbers worked at a chemical plant, in which chemicals for use in the rubber plant are manufactured, and at a rubber reclaim plant.

Since 1900, a card has been kept by the company for each employee. Data include name, social security number (since 1937), race, sex, date of birth, date first employed, date when employment terminated, last department worked, and reason for termination (death, pension, left employment). This file is complete for persons who were employees on or after January 1, 1940. Since the early 1940's, all employees receiving wages have been union members.[1] Since its date of organization in 1933, the local union has maintained a dues file for each member. This file. includes name; social security number (since 1937) and date of joining the union. Also, information on the departments in which an employee worked after 1933 was available. A four-digit code has been used to identify each department. Almost without exception, the same code has been used for each department from 1933 to the present. Whenever an employee changed departments, the new department number was entered sequentially on the dues card. The date of the change was often not recorded, but each dues card lasted 4 or 6 years, so the year of the change could be estimated.

During the years of this study 271 departments have been in existence (table 1). These departments are organized into seven divisions. For the purposes of this study, a sectional grouping within some of the divisions was made of similar departments. As seen in table 1, there is a great disparity in the number of departments per section or per division. The tire curing section, in which 1092 employees worked, is a single department, while the processing division has had 35 departments and 2426 employees.

An employee's departmental work experience was categorized in two ways: ever and usual. For example, there were 319 employees whose longest employment was in the chemical division. There were an additional 465 employees who worked in the chemical division at sometime but whose longest employment was elsewhere in the company. The determination of an employee's longest divisional employment, was based only on the work experienced after 1933 since no departmental information was available before that year. Prior to 1952, transfer from one division to another was uncommon because of work rules, so it is unlikely that much misclassification mas introduced. The average age started, year started, and years worked refer to total employment by the company rather than employment in the specific divisions or sections.

Over 60 per cent of the employees were laid off for 3 months or more at some time during their term of employment. This time spent out of employment was included in the years employed by the company and was considered to be an eighth "division." The 1432 persons whose usual status was in the "laid-off" division were laid off for an average of 5 years. while all other employees were laid off for an average of 1.5 years.

The chemical plant produces chemicals used in making rubber, mainly in closed systems. Products produced by the aerospace division were mainly fuel cells (gas tanks) and pneumatic de-icers for airplanes. The tire division has three sections: a) tire building, where uncured rubber is used; b) curing, where tires are cured in large presses; and c) miscellaneous, which includes tire finishing and manufacturing of tubes and truck tires. Small rpbber products are made in the industrial products division (e.g., rubber bands, hoses, belts, and molded rubber goods). The serv-

[1] In contrast to "salaried employees" who are part of management.

TABLE 1

Number of departments and characteristics *of* employees, according to plant division and section

Division and section	No. of departments	No. of employees*		Average employment data†		
		Ever	Usual	Age started	Year started	Years worked
"Laid off'		8482	1432	25	1937	14
Chemical	11	784	319	28	1941	23
Aerospace	18	3207	1051	26	1937	24
Tires						
Tire building	6	3491	1905	25	1933	28
Tire curing	1	1092	538	30	1930	29
Miscellaneous	21	3141	1045	28	1930	28
Industrial products						
Plant 4	27	1639	475	28	1933	24
Hose/belt	29	1844	1248	27	1936	25
Miscellaneous	22	2889	624	27	1935	24
Services						
Engineering	26	548	165	35	1933	22
Operating	24	1023	355	29	1935	25
Warehouse/shipping	9	1625	736	28	1931	28
Elevator/cleaning	5	974	418	38	1931	24
Shops	27	2474	1834	32	1933	29
Rubber reclaim	10	1261	306	29	1938	23
Processing	35	2426	1118	30	1931	25
Total	271		13.551	28	1931	24

* Ever is number ever employed in section; usual is number whose longest job was in section.
† Age and year first employed by company; total years worked in company.

ices division includes a variety of departments, whose employees work throughout the plant or with a variety of products. The rubber reclaim division is a separate plant where used rubber is ground up and reprocessed. In the processing division, the raw materials of rubber are weighed and mixed together, and the resultant hot raw rubber is milled into a variety of forms.

Follow-up. Approximately 32,000 white male union members were identified from the union and company files. Over 18,000 men who worked fewer than 5 years are not included in this report. For workers first employed in 1935 or later, follow-up started on the fifth anniversary of employment. For workers first employed prior to 1935, follow-up started on January 1, 1940. The study cohort consisted of 13,571 men. As of June 30, 1971, when this study was initiated, there were 2610 active employees, 2988 who were pensioned, 3809 who were known to be deceased and 4164 who had terminated employment. Among the group of terminated employees, 3694 worked less than 15 years, 268 worked 15–24 years and 202 worked 25 years or more. The percentage of terminated employees and the distribution of years worked were similar among the employees of the various plant divisions.

Determination of the status of the employees who had terminated employment prior to pension was conducted with the assistance of the Internal Revenue Service and the Social Security Administration. The last known year of filing an income tax return was in 1972 for 695 of these men and in 1973 for 1954 men. These 2649 former employees were considered to be live withdrawals on January 1st of the year in which the return was filed.

Of the remaining 1515 terminated employees, 739 were found to have died be-

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tween January I, 1940 and July 1, 1973, on the basis of Social Security death claims. The other 776 employees were considered to be live withdrawals on July 1, 1973. Approximately 70 per cent of these were known to be alive on the basis of earnings or benefits paid during 1973. The status of the remaining 30 per cent was unknown, but no death claim had been filed with the Social Security Administration.

Follow-up of active and pensioned employees was continued until July 1, 1974. Of the 2610 employees who were active on July 1, 1971, 1561 were still active 3 years later. Twenty had died, 508 had retired and most of the remaining 521 employees had been laid off during 1974. Of the 2988 former employees who were on the pension rolls on July 1, 1971, 511 were known to have died during the next three years. Employees who were active or pensioned on July 1,1971, and who were not known to have died during the next 3 years, were considered to be live withdrawals on July 1, 1974.

For most of the 5079 persons known to be deceased, a copy or abstract of the death certificate was obtained. The cause of death was coded by a nosologist at the National Institute for Occupational Safety and Health according to the system in effect at the time of death. The code assigned was then translated to the four-digit International Classification of Diseases (ICD) Code. Seventh Revision. Death certificates could not be found for 97 (2 per cent) of the deceased employees. No correction to the cause-specific standard mortality ratios (SMR) was made because of the non-availability of these certificates.

Computation of ***expected numbers of deaths.*** The numbers of deaths observed assigned to specific causes were compared to the numbers expected. In computing the expected numbers, the person-years of survival of the study cohort were determined in 5-year age-time intervals. The number of person-years in each age-time cell was multiplied by the age-time-cause-specific mortality rate for United States white males. The rates used were time-specific for each 5-year time group from 1940–1969. The rates from 1965–1969 were used for 1970–1974. The expected numbers in each cell were summed over age and time to yield a total expected number for each 57 categories of cause of death (8).

The expected numbers of cause-specific deaths were also calculated using death rates for Ohio males. In general, the results were the same as those obtained using United States rates. Further, there are no major differences between death rates for white males in Summit County, the location of the plant, and for the United States (9). Examples include (age-adjusted rates per 100,000, Summit County/United States): all cancer (185.5/174.0), stomach cancer (16.2/15.2), large intestine cancer (19.6/16.5), lung cancer (39.0/38.0), brain cancer (5.4/4.4), bladder cancer (8.0/6.8), and leukemia (9.3/8.8). Any excess mortality among rubber workers would, of course, be included in the rates for Summit County.

Proportional ***mortality, 1925–1939.*** Prior to 1940, it was not possible to compute expected numbers of deaths on the basis of death rates. However, the cause of death of 688 white male employees was known. Therefore, expected numbers of cause-specific deaths were calculated on the basis of proportional mortality ratios. The observed number from all causes was categorized into 5-year age-time-specific groups and age-time-specific proportional mortality ratios for United States white males were multiplied across each of these strata to calculate the expected number of cause-specific deaths (8). Only the last department in which a man had worked was available for this group of employees.

Statistical considerations. No tests of statistical significance are given. Since the overall SMR was 82, testing whether the SMRs for specific causes of death differ

from 100 does not seem indicated. Also, inclusion of department-disease associations and of age-time categorizations depended to some extent on examination of the data, and tests of statistical significance would not be appfopriate.

RESULTS

The causes of death of the 5079 deceased employees are presented in table 2. The numbers expected on the basis of United States mortality rates are also presented. These are related using the SMR: (100 x observed/expected). The overall SMR of 82 indicates that this group of rubber workers experienced mortality which was only 82 per cent of that expected. Causes in which the SMR was 95 or above include leukemia and cancers of the stomach, large intestine, bladder and lymphatic system. Causes in which the SMR was 70 or below include all infective and parasitic diseases, cancer of the buccal cavity and pharynx, diseases of the respira-

TABLE 2

Observed and expected deaths according *to cause**

	ICD No.† and cause of death	Observed	Expected	SMR‡
	All causes	5059	6186.9	82
001-139	Infective and parasitic diseases	51	152.0	34
140-205	Malignant neoplasms	980	1046.4	94
140-149	Buccal cavity and pharynx	19	36.1	53
150-159	Digestive organs and peritoneum	364	371.6	98
150	Esophagus	24	26.4	91
151	Stomach	98	93.9	104
153	Large intestine	104	103.1	101
154	Rectum	42	47.2	89
155, 156	Liver and biliary passages	30	33.8	89
157	Pancreas	53	60.3	88
161	Larynx	12	17.0	71
162.163	Lung	234	233.1	92
177	Prostate	82	89.0	92
180	Kidney	19	24.8	77
181	Bladder	48	39.5	122
193	Brain	20	25.1	80
200-203	Lymphatic and myeloma§	51	50.4	101
204	Leukemia	55	13.0	128
260	Diabetes mellitus	81	90.i	93
330-334	Vascular lesions of central nervous system	493	539.6	91
400-468	Diseases of circulatory system	2445	2943.2	83
420	Arteriosclerotic heart disease	1826	2155.9	85
470-527	Diseases of respiratory system	218	321.4	68
530-587	Diseases of digestive system	215	284.0	76
590-637	Diseases of genito-urinary system	74	140.0	53
800-998	Accidents, poisoning, violence	278	446.8	62
600-936	Accidents	184	320.4	57
970-979	Suicide	72	105.8	68
	All other causes	142	222.8	64
	Unknown causeofdeath	97		

* Expected numbers based on 5-year age-time specific death rates for United States white males.
† International Classification of Diseases. Seventh Revision.
‡ Standard mortality ratio: 100 x observed deaths/expected deaths.
§ 1950 and later only for codes 200. 202, 203.

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There were **253,026** person-years of follow-up accumulated by active and pensioned employees, and 88,414 person-years accumulatkd by former employees following the date of termination. If deaths occurring only while on active or pensioned status are considered, the SMR was **85** for all causes **(4340** observed, **5082** expected) and 100 for all cancers **(850** observed, 851 expected). Seven hundred thirty-nine of the terminated employees were known to have died following termination, while 1211 deaths were expected (SMR = 61). (The SMR was 81 if expected numbers were calculated using the death rates of employees on active or pensioned status.)

In table **3,** mortality from all causes of death and from all cancers is considered according to five characteristics of employment. In computing the SMRs for age or year when an employee started working. all person-years were grouped within a specific category. For example, for the "year started working" categories, **SMR's** for three independent cohorts were calculated. For the "years worked" grouping, the person-years for an individual were included in more than one category. For example, follow-up of an individual in the **"≥35"** category did not begin until the 35th anniversary **of** employment. The 30 person-years accumulated prior to that time were allocated equally to the other three categories.

In considering the data in table **3,** it must be emphasized that there are correlations among the person-years of the five characteristics. **A** person who worked for **35** or more years must have started work before age 30 and before 1940. However. the main point of emphasis is that the SMRs within each characteristic do not differ greatly. For example, employees who started working before 1925, when industrial hygiene was presumably not as highly developed as in later years, have SMR's for all causes and all cancers which are similar to those for other employees. The highest SMR is that of **130** for deaths from cancer in persons who died at age 75 and over.

The mortality experience was examined for groups of workers categorized by plant division in two ways (table 4). Under the category "ever worked," an employee is counted in each division in which he worked (an average of 1.85 divisions per employee). Under the category "usually worked" each employee is counted only once. The SMRs under "ever worked'' tend to be less than those under "usually worked" because of an inverse relationship between the **SMR** and the number of divisions in which a person worked. Except for employees whose usual status was in the laid off division, the SMRs for all cancers were higher than the **SMRs** for all causes. The range of the **SMR** for all causes was 72 to 87, and for all cancers from 69 to 111.

Calculations of observed and expected deaths, as shown in tables 2 and **4,** were

TABLE 3

Standard mortality ratios (and observed deaths) for all causes and for all cancers, according to selected characteristics

Characteristic	Category (years)	All causes	All cancers
Age started working	<25	73 (990)	81 (193)
	25-34	80 (2002)	91 (395)
	35-44	94 (1471)	109 (278)
	≥45	83 (616)	98 (114)
Year started working	<1925	86 (2040)	92 (349)
	1925-1934	80 (1740)	100 (378)
	≥1935	79 (1299)	88 (253)
Years worked	5-14	73 (903)	90 (176)
	15-24	81 (1286)	87 (228)
	25-34	87 (1770)	100 (345)
	≥35	84 (1120)	96 (231)
Age at death	<55	69 (890)	81 (158)
	55-64	74 (1233)	78 (255)
	65-74	88 (1681)	97 (349)
	≥75	97 (1275)	130 (218)
Year of death	<1955	74 (1187)	86 (209)
	1955-1964	87 (1754)	100 (362)
	≥1965	83 (2138)	92 (409)

TABLE 4

Standard mortality ratio (and observed deaths) for all causes and all cancers, according to plant divisions in which employees ever and usually worked

Division	Average survival characteristic:;		Ever worked		Usually worked	
	Age at entry	Year of entry	All causes	All cancers	All causes	All cancers
"Laid off'	32	1945			81 (319)	69 (44)
Chemical	34	1948	74 (161)	85 (32)	74 (68)	80 (13)
Aerospace	33	1945	14 (711)	92 (155)	81 (282)	89 (55)
Tires	38	1943	79 (19683	92 (397)	81 (1345)	93 (265)
Industrial products	37	1945	76 (1600)	84 (309)	81 (796)	94 (159)
Services	42	1944	83 (2238)	90 (405)	84 (1638)	94 (305)
Rubber reclaim	37	1946	75 (313)	94 (68)	72 (93)	100 (22)
Processing	41	1943	79 (833)	98 (177)	87 (538)	111 (117)
Total	38	1944			82 (5079)	94 (980)

• Age and year of entry refer to follow-up.

TABLE 5

Observed and expected deaths *due to selected diseases, according to work* area in which employee *usually* worked

Disease	Work area	No. of deaths		Standard mortality ratio
		Observed	Expected	
All gastrointestinal cancer	Processing	52	38.2	140
	Rubber reclaim	11	7.1	140
Stomach cancer	Processing	18	9.9	190
Large intestine cancer	Processing	14	10.5	130
Pancreas cancer	Elevator/cleaning	6	2.9	210
Lung cancer	Tire curing	20	12.4	160
Prostate cancer	Miscellaneous tire	12	8.8	140
Bladder cancer	Warehouse/shipping	8	2.6	310
	Tire building	9	4.8	190
Brain cancer	Tire buildinp	7	3.7	190
Lymphatic cancer and myeloma	Tire building	11	7.1	160
Leukemia	Tires	18	11.7	150
	Processing	10	4.2	240
Asthma	Services	11	7.0	160
Diabetes	Warehouse/shipping	11	5.8	190
Vascular diseases of central nervous system	Operating services	19	14.1	130
Pneumonia	Tire curing	12	7.7	160

done for employees of each division and section. **Work** areas with excess deaths due to specific causes are listed in table 5. The following arbitrary criteria were used for inclusion in this table: at least 5 deaths from a specific disease, at least three excess deaths in the work area in which an employee usually worked, and an SMR of 130 or greater. In general, excess observed deaths were not found among employees who worked in a section for short periods of time. In other words, any excess deaths

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among the "ever worked" grouping were accounted for by the "usually worked" grouping. There were two exceptions: 11 deaths from lung cancer (8.5 expected) among employees who worked in the tire curing section but for whom it was not their usual work area., and 4 deaths from bladder cancer (1.9 expected) among employees of the warehouse/shipping section whose usual work area was in another section.

The departmental experience of employees who died of the diseases listed in table 5 was examined. The excess of gastrointestinal cancer in the rubber reclaim division resulted from 4 deaths from cancer of the esophagus (0.6 expected). The excesses of gastrointestinal cancer and of leukemia in the processing division were spread throughout a number of departments. However, it is of interest that among men whose usual department was calendering, 2 had cancer of the small bowel and 2 had cancer of the nasopharynx. Among the entire cohort there were only 3 and 4 such deaths, respectively.

Tire building had excesses of bladder and brain cancer as well as cancers of the lymphatic and hematopoietic systems. Of the four brain tumors for which the cell type was specified on the death certificate. three were gliomas and one was an astrocytoma. There were seven deaths from lymphoma, three from Hodgkin's disease, and one from multiple myeloma.

Excess deaths from leukemia occurred most often among workers in the tire and processing divisions. However, excesses were also seen among workers in the chemical division (2 observed, 0.7 expected), elevators and cleaning (3 observed, 0.4 expected), shops (7 observed, 6.6 expected), and industrial products (9 observed, 7.0 expected).

The excess of deaths from asthma, diabetes and vascular disease of the central nervous system occurred in a number of departments. The excess of deaths from pneumonia in the tire curing section was consistent with the excess of deaths from lung cancer.

Cancers for which the SMR was greater than 90 (table 2) were examined according to the age-time characteristics used in table 3. In table 6, the breakdown for bladder cancer, lymphatic cancer and leukemia are presented for the entire cohort. The data for gastrointestinal cancer are given only for men who usually worked in processing. (The patterns in the SMR's for stomach and large intestine cancer among processing workers were similar.) The data for lung cancer are given for all men who ever worked in tire curing.

The following observations are made based on the data in table 6: 1) Excess gastrointestinal cancer occurred in all categories, and was greatest in processing workers who died at age 75 and above. 2) Excess lung cancer was limited to tire curing workers who started work between ages 25 and 34 and who died in 1955 or later. 3) Excess bladder cancer was greatest in men who worked at least 35 years and who died at ages 75 and above. No excess risk was present in men who started working after 1934 or who died before 1955. (In men who started working between 1930 and 1934, there were 7 deaths from bladder cancer and 5.1 expected). There was no association of the SMR with the age men started working. 4) In men who started working before age 25, an excess was seen for leukemia but not for lymphatic cancer and myeloma. There was no evidence for an excess of either category of cancer in men who started working after 1934.

If excess cancer in fact had occurred among rubber workers because of their work experience, it might be expected that some minimum number of years of exposure would be necessary for induction of the cancer. Therefore, standard mortality ratios for each cause of death were calculated for men who worked at least 25 years. Follow-up started on the 25th anniversary

of employment. The overall SMR was 86 and that for cancer was 98 (table 7). In general, the SMR's for each cause were no more than 10 per cent greater than those in table 2, and some were less. The only large difference was for leukemia, where the SMR was 160 rather than 128. The age-time patterns for all causes, all cancer, bladder cancer, and leukemia are presented in table 7.

The patterns for all causes and all cancers are similar to those in table 3. Cancer was relatively uncommon before 1955 and showed the greatest excess in men who died at age 75 and over. Bladder cancer especially had this pattern. Because an excess of bladder cancer occurred only in men who died at a relatively advanced age, it is difficult to determine whether the men first employed after 1934 have an excess risk. In contrast to the data in table 6. there is no evidence that the risk of leukemia is reduced in men who started working after 1934, although only three such men have died from leukemia.

In the entire cohort there were only two deaths from cancer of the salivary glands and eight deaths from cancer of the gallbladder and bile ducts. No common work experience could be ascertained among these workers; only one person with cancer of the bile ducts worked (for 1 year) in the processing division.

Table 8 gives the results of a proportional mortality analysis for persons who died between 1925 and 1939. By definition, the expected number of deaths from all causes is equal to the observed number. On a proportional basis, deaths from diseases of the circulatory system and from accidents. poisoning and violence were slightly greater than expected. Deaths from cancer were not in excess. The three employees who died from brain cancer worked last in processing, tire building and an undetermined department in the tire division.

TABLE 6

Standard mortality ratios (and observed deaths) for selected cancers, according to selected characteristics

Characteristic	Category (years)	Gastro-intestinal cancer.	Lung cancer†	Bladder cancer‡	Lymphatic cancer and myeloma‡	Leukemia‡
Age started working	<25	120(7)	90(4)	110(7)	90(14)	180(19)
	25-34	120(22)	220(24)	130(21)	110(22)	100(18)
	≥35	160(23)	50(3)	61 (20)	110(15)	120(18)
Year started working	<1925	130(21)	130(8)	140(24)	100(14)	140(21)
	1925-1934	130(22)	200(14)	140(19)	120(22)	160(25)
	≥1935	160(9)	120(9)	60(5)	80(15)	70(9)
Years worked	5-24	150(24)	130(11)	110(17)	100(24)	90(18)
	25-34	140(20)	140(10)	100(14)	90(13)	170(23)
	≥35	100(8)	200(10)	170(17)	120(14)	150(14)
Age at death	<65	110(18)	140(17)	100(14)	100(29)	120(25)
	65-74	110(16)	140(10)	90(13)	100(15)	150(21)
	≥75	250(18)	220(4)	220(21)	110(7)	110(9)
Sear of death	<1955	110(13)	70(2)	90(8)	130(12)	120(12)
	1955-1964	160(21)	160(12)	140(17)	90(17)	150(23)
	≥1965	130(18)	160(17)	130(23)	100(22)	110(20)

• Employees who usually worked in processing.
† Employees who ever worked in tire curing.
‡ All employees.

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TABLE 7

Standard mortality ratios (and observed deaths) in 7374 employees who worked at least 25 years

Characteristic	Category (years)	All causes	All cancers	Bladder cancer	Leukemia
Age started working	<25	76 (646)	86 (140)	130 (7)	260 (16)
	25-31	84 (1461)	97 (296)	140 (18)	110 (13)
	≥35	100 (783)	117 (140)	100 (6)	170 (8)
Year started working	<1925	89 (1762)	95 (307)	140 (21)	150 (20)
	1925-1934	84 (915)	104 (215)	120 (9)	180 (14)
	≥1935	52 (213)	91 (54)	60 (1)	140 (3)
Age at death	<65	72 (891)	81 (191)	100 (7)	180 (15)
	63-74	89 (1140)	99 (241)	90 (9)	180 (17)
	≥75	100 (859)	131 (144)	240 (15)	100 (5)
Year of death	<1955	80 (494)	73 (75)	0 (0)*	230 (8)
	1955-1964	90 (1019)	111 (229)	190 (15)	190 (15)
	≥1963	85 (1377)	97 (272)	140 (16)	120 (14)
Total		86 (2890)	98 (576)	130 (31)	160 (37)

*Expected = 4.2.

TABLE 8

*Observed and expected deaths for all white male Akron employees, 1925-1939**

ICD No.†	Cause of death	Observed	Expected
	All causes	688	688.0
140-205	Malignant neoplasms	63	62.6
150-159	Digestive organs and peritoneum	31	33.7
162, 163	Lung	6	4.3
181	Bladder	2	2.4
193	Brain	3	1.2
200-205	Lymphatic and hematopoietic	4	3.8
330-334	Vascular lesions of central nervous system	38	36.2
400-468	Diseases of circulatory system	169	150.8
800-998	Accidents, poisoning, violence	141	129.3
	All other causes	277	309.1

* Expected numbers based on 5-year age-time-specific proportional mortalities for United States *white* males.

† International Classification of Diseases. Seventh Revision.

DISCUSSION

A central issue in mortality studies among occupational groups is the choice of a comparison group. A number of possibilities exist as a comparison group for Akron rubber workers: 1) Another group of employed persons in Akron. Assuming that such a group could be identified, the size and cost of this study would have been doubled. Also, there would be no guarantee that such a group would have no unusual mortality patterns of its own. Finally, the death rates obtained from such a group would be based on relatively small numbers of deaths and would be quite unstable. 2) Salaried B.F. Goodrich employees in Akron. The death rates for this group of employees are quite unstable. Also, any confounding effects of socio-economic factors on mortality would likely be maximized in such a comparison. 3) Ohio death rates. The cause-specific mortality rates for Ohio white males are virtually identical to those for United States white males. United States rates were used because they are available in greater detail. 4) Summit County rates. Such rates are not available. 5) Mortality rates from an occupational cohort from Social Security records. The development of such rates has been suggested (10). While these rates would be of great value, they currently are not avails-

ble. Until this resource has been developed, rates from the general population must be used.

In studies of mortality where expected deaths are computed using death rates for some general population, standard mortality ratios less' than 100 are common because of the relatively healthy status of most employed groups (10). In this study, death rates for all United States white males were used because they are the only rates readily available in sufficient cause-sex-race-age-time-specific detail. Also, inclusion of the terminated employees leads to an underestimation of the SMR. Finally, the non-availability of death certificates for 2 per cent of those known to be deceased would further reduce the cause-specific SMRs: Thus, for methodologic reasons, any SMR resulting from this study which reflects a causal association is likely to be an underestimate of the true SMR in the population of rubber workers. The following SMRs for all causes of death among rubber workers have been reported: 56, U.S. Vital Statistics Special Study (7);89, U.S. group life insurance records (11);97, British rubber and cable workers (5); 99, American rubber workers (6).

It is never possible to determine which SMRs reflect causal association and which do not. A large number of SMRs have been calculated and random increases are likely. In selecting associations to be presented in this paper, arbitrary criteria were set up and all associations meeting those criteria are presented. These are the associations which are based on the largest number of observed deaths and thus are the most stable. The judgment as to whether an association is causal must depend upon external considerations: consistency with knowledge of the rubber-making process and consistency with other studies of mortality. However, with respect to actions to be taken within the plant being studied, caution must be exercised. If a disease is found to have occurred with excess frequency in some work area, and no obvious reason for selection with respect to that disease can be found, measures should be taken to reduce possible harmful exposure.

Workers in the processing division had an excess of deaths from cancer of the gastrointestinal tract. Specific jobs held by men who worked in this division include rubber compounding, mixing, milling and calendering. In these areas there is considerable exposure to dusts and fumes. By weight, the most common substance added to rubber is carbon black, which strengthens the rubber. Carbon black contains impurities, some of which have been shown to be carcinogenic in animals (12-14). In a rubber worker who died from carbon pneumoconiosis, areas of the gastric mucosa were found to be infiltrated with carbon black (15). However, no excess of cancer deaths was found in one study of carbon black workers (two observed, five expected) (16, 17).

Excesses of cancer of the bronchus among tire workers have been reported (3.5). From the current data, workers who cure tires appear to be at increased risk of bronchial cancer as well as being at increased risk of dying of pneumonia. In producing tires. the "green" tire is cured in a press under heat and pressure. Repeated exposure to the curing fumes was common in curing workers since in the past the cured tire had to be removed from the press by hand. Most curing presses now are automated. Workers in this area have also been shown to have an excess of respiratory signs and symptoms as compared to other members of the plant population (18). The cigarette smoking habits of current curing workers are similar to those of workers in other areas of the plant (18).

A greater incidence of cancer of the urinary bladder among rubber workers has been recognized for many years (1,19,20). The probable cause is beta-naphthylamine, a possible contaminant in antioxidants added in processing rubber. (There

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were 5 deaths from bladder cancer observed and 4.1 deaths expected among workers who usually worked in the processing division). The excess of bladder cancer in shipping and warehouse workers is difficult to explain. A similar finding has been reported in shipping'workers in an English rubber works, although a greater excess was seen among processing workers (19). Products in which beta-naphthylamine was a contaminant have not been used in rubber manufacture since the late 1940's (5). If it is the agent responsible for bladder cancer in rubber workers, persons first employed as rubber workers in recent years should not have an increased risk. In the data reported here, no excess of bladder cancer is seen in employees who started work after 1934, or who died before 1955. However, since the excess risk of bladder cancer is greater primarily in those who died at age 75 and older, it may not yet be concluded that the cause of bladder cancer has been eliminated.

It has been reported that excess bladder cancer among rubber workers was limited to men who started working before age 25 (21). No supporting data were found among this group of rubber workers.

The overall excess from leukemia among workers in several divisions suggests a general exposure. Organic solvents are used in many processes, and benzene in particular has been used extensively in the industry and has been suggested to be leukemogenic (22. 23). While pure benzene is no longer used as a solvent it is a contaminant in many of the solvents still used (24). A general association between solvent exposure and lymphatic leukemia in another group of rubber workers has been reported (25).

No hypotheses are offered for the excesses of brain and lymphatic cancers among tire builders. These men are exposed to organic solvents and cements, as well as to uncured rubber.

Based on the data in this and other studies among rubber workers, attention should be directed to identify specific substances which may be responsible for gastrointestinal cancer in processing workers, lung cancer in tire curing workers, brain cancer in tire builders and leukemia in all rubber workers.

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