

Cancer Mortality and Morbidity Among Rubber Workers^{1,2}

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ABSTRACT—Mortality and morbidity from cancer among a cohort of 13,570 white male rubber workers were examined. Each man worked for at least 5 years at the Akron, Ohio, plant of the B. F. Goodrich Company. The potential period of follow-up was from January 1, 1940 to June 30, 1976. Departmental work histories were based primarily on records maintained by Local 15, United Rubber Workers. The Occurrence of cancer was measured by death certificates and by a survey of Akron-area hospital tumor registries from 1964 to 1974. Two types of analyses were made: 1) an external comparison of mortality rates of rubber workers versus rates of U.S. white males, and 2) an internal comparison of cancer morbidity rates among persons who were employed in various work areas of the plant. Excess cases of specific cancers (observed/expected numbers) among workers in specific work areas included: stomach and intestine: rubber making (30/14.4); lung: tire curing (31/14.1), fuel cells and/or deicers (46/29.1); bladder: chemical plant (6/2.4), and tire building (16/10.7); skin cancer: tire assembly (12/1.9); brain cancer: tire assembly (8/2.0); lymphatic cancer: tire building (8/3.2); and leukemia: calendaring (8/2.2), tire curing (8/2.6), tire building (12/7.5), elevators (4/1.4), tubes (4/1.6), and rubber fabrics (4/1.1). Agents that may be responsible for these excesses were considered.—J Natl Cancer Inst 61: 1047-1053, 1978.

In March 1976 two reports were published in which the mortality experience of rubber workers at the B. F. Goodrich Company, Akron, Ohio, between January 1, 1940, and June 30, 1974, was described (1, 2). Excesses of several cancers were seen in groups of employees who worked in specific departments. An employee was considered to have died from cancer only if cancer was specified as the underlying cause of death on the death certificate. Most of the analyses were based on the department in which an employee had worked the longest.

In the present report, more details are considered with respect to the cancer experience and the work experience of the Akron employees. Two additional years of cancer mortality have been accumulated, and all cases of cancer that have been identified have been included. An employee's departmental work experience has been defined as the number of years he was estimated to have worked in the various departments. This estimate provides a rough measure of exposure to the environmental conditions that prevailed.

METHODS

Definition of population.—B. F. Goodrich employees included in this report were the white male union members whose mortality experience was previously described (1). (Since the early 1940's, all wage employees have been union members.) One person was excluded because of an error in the data; this left a study population of 13,570. Included was any Akron employee who worked for at least 5 years prior to July

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1, 1971. The potential period of follow-up was from January 1, 1940, through June 30, 1976.

Definition of cancer.—In the previous report (1), a person was defined as having cancer only if it was the underlying cause of death. In the present report, two additional criteria have been used: 1) Cancers that were listed on the death certificate but were not the underlying cause of death were included. 2) A survey was made of the tumor registries of four Akron-area hospitals (Akron City, Akron General, St. Thomas, and Barberton Citizens). B. F. Goodrich employees whose cancers were diagnosed between approximately 1964 and 1974 were identified in this survey; these cancers were also included.

In the original report, 980 men were determined to have died from cancer between January 1940 and June 30, 1974. In the current study, an additional 379 cases of cancer have been identified. Of these, 68 were the primary cause of death between June 30, 1974, and June 30, 1976; 81 were a secondary cause of death between January 1, 1940, and June 30, 1976; and 230 were incident cases identified solely from the Akron registries.

We have essentially complete identification of fatal cancers in this population and an incomplete ascertainment of the nonfatal cancers. Therefore, a comparison with an external population can be made only for mortality data. In analyses with morbidity data, we have used internal comparisons (see "Analysis of data"). Inasmuch as the identification of nonfatal cases of cancer was made without knowledge of a person's work experience, the incomplete ascertainment should not lead to any important bias in within-plant comparisons.

Validation of diagnosis of cancer.—The diagnosis of cancer among Akron employees was made initially from death certificates or from rosters compiled from hospital tumor registries. For each person who worked

ABBREVIATIONS USED: BNA= β -naphthylamine; ICD=International Classification of Diseases; PAH=polycyclic aromatic hydrocarbons; PBNA=phenyl- β -naphthylamine.

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in a department whose employees were found to have an excess rate of a specific cancer, an attempt was made to verify the diagnosis. If a person died in a hospital, that hospital was contacted and more details from the medical record were sought. If a person was identified from a hospital tumor registry, the patient's medical record was reviewed by the hospital to verify the diagnosis.

In general, the initial data were accurate. However, autopsy sometimes revealed that the person did not have cancer, or we found in a few instances that the person was not the B. F. Goodrich employee of the same name. Because corrections were made only for departments in which excess cancer was suspected, no false-positive associations were made. If anything, this procedure led to a slight underestimate of the size of an association between a department and a type of cancer.

Definition of departmental "work" experience.—No precise data were available from company or union records as to the work experience of employees. The data used were obtained primarily from the files of the union. On the dues cards was entered the four-digit number of the department in which the employee was working. Whenever an employee changed departments, the new departmental number was entered in sequence. Although the date of the change was not recorded, a new card was made out every 4 or 6 years. Therefore, the period when an employee worked in a specific department was known, and the actual year of entry into the department could be estimated.

Prior to 1933, no departmental information was available from union records. All that was generally available from company records was the service date, that is, the year of employment adjusted for layoffs. In this analysis, the years between the service date and 1933 were assumed to be spent in the same department that the employee was in when the union was organized in 1933. This probably is a reasonable approximation: Prior to 1952 transfers from one plant division to another were uncommon, and consequently the opportunity to transfer from one department to another was limited.

Analysis of data.—The first step was to analyze the mortality experience from January 1, 1940, to June 30, 1976, of all employees as compared to U.S. white males (3). On the basis of an apparent excess of one or more cancers, specific departments were selected for further analysis. Grouping of departments was done when an excess of specific cancers was seen in departments that had similar industrial processes or exposures. Employees in departments with no excess of a specific cancer were grouped together as "residual" employees.

Next, age- and time-standardized morbidity rates were computed for specific cancers in specific departments, with the use of data on all incident cancers. The standard used was the age-specific person-years distribution of all 13,570 employees. The standard error of the standardized rate was computed (4).

Analyses were next done according to the number of years an employee worked in a department or group of departments. If an excess of cancer was seen only in men who had worked some minimum number of years in a department (for example, 5), in subsequent analyses men who worked 0-4 years were not included. An advantage of this exclusion was that overlap of departmental experience was greatly reduced. Therefore, whereas a hierarchical grouping of work experience was used, there was no important uncertainty as to which department an individual belonged.

Finally, a direct comparison was made between employees in departments with an excess of a specific cancer and employees in residual departments. The observed numbers of cancer among employees in selected departments were distributed according to characteristics of age and time. The numbers expected among these employees were computed on the basis of the age-specific rate of cancer in the group of residual employees. These comparisons are illustrated in table 2.

RESULTS

Stomach and Intestinal Cancer

As seen in table 1, stomach cancer (ICD code 151, 7th

TABLE 1.—Mortality and morbidity from cancer of the stomach or intestine according to work area

Work area and minimum years in area ^a	No. of persons ^b	Reported No. of deaths ^c				Cumulative No. of cases ^d					
		Observed		Expected ^e		Total cases		Standardized rate ^f		Rate ratio	
		Stomach	Intestine	Stomach	Intestine	Stomach	Intestine	Stomach	Intestine	Stomach	Intestine
Rubber making, ^g	718	12	13	5.7	6.5	13	17	63 (18)	78 (19)	2.2	2.0
5+ yr											
Solid tires/track, ^g	307	4	8	2.1	3.0	4	9	41 (20)	89 (30)	1.4	2.3
5+ yr											
Residual	12,545	82	86	86.1	94.5	92	122	29 (3)	38 (3)	1.0	1.0
Total	13,570	98	107	93.9	104.0	109	148				

^a Employment in work areas is mutually exclusive and hierarchical from the top.

^b No. of persons who worked at least the minimum number of years in the area.

^c Deaths occurring during the period January 1, 1940-June 30, 1974.

^d Cases occurring during the period January 1, 1940-June 30, 1976.

^e Calculated on the basis of U.S. mortality rates for white males.

^f Rate/100,000 persons/yr. Standardized by the direct method to the age-specific person-year distribution of all 13,570 persons. Values in parentheses are SE.

^g Includes compounding, mixing, milling, and testing.

TABLE 2.—Observed and expected cases of stomach and intestine cancer in selected departments, according to selected characteristics*

Characteristic	Category	No. of cases among workers in rubber making ^b		No. of cases among workers in solid tires/tracks ^b	
		Observed	Expected	Observed	Expected
Age started working in department, yr	<35	13	6.7	5	2.2
	35-44	15	4.5	2	1.9
	≥45	2	3.2	6	2.2
Yr started working in department	<1925	3	3.9	5	1.6
	1925-1939	20	7.4	3	1.3
	≥1940	7	3.0	5	3.4
No. of yr worked in department	5-14	11	5.8	7	3.8
	15-24	11	4.7	1	0.9
	≥25	8	3.8	5	1.6
Age at cancer occurrence, yr	<65	10	5.8	2	2.6
	65-74	11	4.9	5	2.0
	≥75	9	3.6	6	1.7
Yr of occurrence	<1960	6	5.6	4	2.2
	1960-1969	16	5.5	5	2.5
	≥1970	8	3.2	4	1.6

* Expected cases were calculated on the basis of age-specific morbidity rates for residual employees, as defined in table 1.

^b Minimum of 5 yr in work area.

revision) was increased in men who worked at least 5 years in rubber making (compounding, mixing, milling, and testing laboratories). Intestinal cancer (ICD 152, 153) was increased in men who worked at least 5 years in rubber making and in those who worked at least 5 years in solid tires/tracks. As seen in table 2, the excess of cancers of the stomach and intestine among men who worked at least 5 years in rubber making occurred primarily in those who started working before age 45, who started working after 1925, and who developed cancer since 1959. For men who worked at least 5 years in solid tires/tracks, the excess was seen only at age 65 and above.

Pancreas Cancer

Pancreas cancer (ICD 157) was increased in two dissimilar departments—elevators and tire curing (table 3). The age-standardized rates in these departments were, respectively, 3.0 and 2.5 times higher than in men who did not work at least 5 years in one of these departments.

Lung Cancer

Excess lung cancer (ICD 162, 163) was seen in three departmental groupings: tire curing, tire molds, and fuel cells/deicers (table 3). The excess lung cancer occurred only in men who worked at least 5 years in curing or in molds. For fuel cells/deicers, the excess was greater in men who worked 0-4 years than in those who worked a longer period of time. Although several men worked both in fuel cells and deicers, the excess lung cancer was associated with each department independently.

For men who worked in tire curing, an excess of lung cancer was seen in each category of the age- and time-standardized characteristics, except for those who started working after age 45 (1 observed, 2.5 expected). The major employment in the fuel cell/deicers departments was during World War II; therefore, few men

started working there prior to 1940. The predominant excess of lung cancer in these men occurred under age 65 (30 observed, 17.6 expected), before 1970 (30 observed, 16.2 expected), and in men who worked fewer than 25 years (45 observed, 28.8 expected).

Prostate Gland Cancer

Two apparently unrelated departments—material conservation and final finish—were identified in which 4 men who had worked at least 25 years developed (and died from) prostate gland cancer (ICD 177). Even though these men were older than the residual group, the age-standardized rates of prostate gland cancer were considerably elevated (table 3). Excess cancer of the prostate gland was also seen in men who worked in machine maintenance, with the greatest excess being seen in those who worked a relatively short time.

Bladder Cancer

Bladder cancer (ICD 181) was seen to the greatest excess in men who ever worked in the chemical plant and in those who worked at least 5 years in tire building (which includes band, bead, and tread production as well as tire assembly). In the previous study (1), men who worked in warehouse/shipping had the greatest excess of bladder cancer. In the data presented in table 3, the excess in these departments is minimal.

Among men who worked in the chemical plant or in tire building, excess bladder cancer was seen only in those who started working in the departments between 1925 and 1940 (13 observed, 5.9 expected) and who worked at least 15 years in the department (18 observed, 9.9 expected).

Skin Cancer

Skin cancer (ICD 190, 191) was seen to excess in men who worked in tire assembly (table 3). This is the work

TABLE 3.—Mortality and morbidity from cancer according to work area

Work area and minimum years in area ^a	No. of persons ^b	Reported No. of deaths ^c		Cumulative No. of cases ^d		
		Observed	Expected ^e	Total cases	Standardized rate ^f	Rate ratio
Pancreas cancer						
Elevators, 5+	259	5	2.0	6	47 (20)	3.0
Tire curing, 5+	660	6	3.6	8	41 (15)	2.5
Residual	12,651	42	54.7	52	16 (2)	1.0
Total	13,570	53	60.3	66	—	—
Lung cancer						
Tire curing, 5+	661	26	15.0	31	150 (27)	2.2
Tire molds, 5+	272	9	5.7	10	136 (43)	2.0
Fuel cells/deicers, 5+	1,139	23	20.0	26	97 (20)	1.4
Fuel cells/deicers, 0-4	1,051	20	12.8	20	134 (34)	1.9
Residual	10,447	156	199.6	196	69 (5)	1.0
Total	13,570	234	253.1	283	—	—
Prostate gland cancer						
Material conservation, 25+	28	4	0.4	4	274 (136)	7.6
Final finish, 25+	88	4	1.2	4	88 (46)	2.4
Machine maintenance, 5+	846	7	6.8	15	59 (15)	1.6
Machine maintenance, 0-4	402	1	2.0	7	75 (28)	2.1
Residual	12,206	66	78.6	111	36 (3)	1.0
Total	13,570	82	89.0	141	—	—
Bladder cancer						
Chemical, 0+	784	2	1.2	6	61 (25)	2.5
Tire building, 5+	1,969	7	5.3	16	36 (9)	1.5
Raw material warehouse/shipping, 0+	513	4	1.7	4	26 (13)	1.1
Finished goods warehouse, 0+	445	4	1.5	5	36 (16)	1.5
Residual	9,859	31	29.8	64	24 (3)	1.0
Total	13,570	48	39.5	95	—	—
Skin cancer						
Tire assembly, 5+	1,299	2	1.8	12	47.0 (14.1)	6.5
Residual	12,271	7	15.2	23	7.2 (1.5)	1.0
Total	13,570	9	17.0	35	—	—
Brain cancer						
Tire assembly, 5+	1,299	7	4.3	8	22.2 (7.9)	3.4
Residual	12,271	13	20.8	17	5.4 (1.3)	1.0
Total	13,570	20	25.1	25	—	—
Lymphatic cancer						
Tire building, 5+	1,969	6	2.3	8	15.7 (5.6)	2.5
Residual	11,601	15	18.9	19	6.4 (1.5)	1.0
Total	13,570	21	21.2	27	—	—
Leukemia						
Calendering, 5+	316	4	1.5	8	57 (21)	3.6
Tire curing, 15+	421	5	1.8	8	50 (18)	3.1
Tire building, 5+	1,957	7	6.1	12	26 (7)	1.0
Elevators, 5+	252	3	1.2	4	46 (29)	2.9
Tubes, 5+	339	4	1.3	4	40 (20)	2.5
Rubber fabrics, 0+	280	4	0.9	4	55 (28)	3.5
Residual	10,005	28	30.2	38	16 (3)	1.0
Total	13,570	55	43.0	78	—	—

^a Employment in work areas is mutually exclusive and hierarchical from the top.^b No. of persons who worked at least the minimum number of years in the area.^c Deaths occurring during the period January 1, 1940-June 30, 1974.^d Cases occurring during the period January 1, 1940-June 30, 1976.^e Calculated on the basis of U.S. mortality rates for white males.^f Rate/100,000 persons/yr. Standardized by the direct method to the age-specific person-year distribution of all 13,570 persons. Values in parentheses are SE.

area where the components of the tire are put together. Most of the skin cancers were of the squamous cell type and 4 were fatal. Since skin cancer is usually not

fatal, most of the skin cancer was ascertained in the hospital tumor registry review, which covered the period 1964-1974. The excess occurred mainly in men

who worked at least 25 years in tire assembly (8 observed, 0.9 expected).

Brain Cancer

Brain cancer (ICD 193) was seen to excess in men who worked in tire assembly (table 3). It occurred only in men under the age of 65 (8 observed, 1.3 expected) and in those who started working after 1925 (8 observed, 1.8 expected). Brain cancer was seen mainly in men who worked less than 15 years in the department (7 observed, 1.4 expected).

Lymphatic Cancer and Leukemia

Lymphatic tumors (ICD 200, 202) were seen to excess in men who worked at least 5 years in tire building (table 3). Leukemia (ICD 204) was seen to excess in men who worked in six different departments. Except for tire building, the rate for leukemia in each of these departments was at least 2.5 times the rate in the residual workers.

These two diagnostic categories were grouped in further analyses. An association of interest is with the year that work in the department started. For men who started working after 1945, no excess leukemia or lymphatic cancer was seen (4 observed, 4.5 expected). Also, only a slight excess was seen in men who worked less than 15 years in one of these departments (10 observed, 8.2 expected).

The specific diagnosis of the leukemias or lymphatic tumors among the men who worked in one of the departments specified in table 3 were: lymphosarcoma, 9 cases; reticulum cell sarcoma, 1 case; malignant lymphoma, 1; lymphatic leukemia, 19; myeloid leukemia, 15; monocytic leukemia, 2; and other and unspecified leukemia, 4.

DISCUSSION

In analyzing these data, we relied heavily upon searching for associations between specific cancers and work in departments in which specific substances were used. We grouped such departments when consistent associations were seen. This strategy was used because of the complexity of the work patterns within the plant and because of general uncertainty as to the nature of the hazard of working in the rubber industry. This strategy requires cautious interpretation of any association. To judge whether any cancer-department association is likely to be causal, independent data must be evaluated. Such data include other studies of mortality and morbidity among human populations and toxicologic studies on animals.

Also, internal consistency in the data can be used. If excesses of a specific cancer are found in departments that have a common exposure, it seems reasonable to consider the possibility that the association is causal. In the analyses in which the cancer morbidity rates in "residual" workers were used to compute the expected number of cases of cancer among workers in specific departments, the resultant patterns of observed-to-expected ratios would largely be independent of the data

searching process used. To the extent that these patterns are in accord with knowledge of exposure patterns, inferences as to causality may be made.

Gastrointestinal Cancer

The excess of cancers of the stomach and the intestines among men who worked in processing tends to support causal association. Excesses of these cancers have been reported in other studies of rubber workers (5-7). These excesses also tended to occur in areas where the ingredients of rubber are compounded and mixed (8-10).

Traditionally, the processing area has been dusty, with a large fraction of the nonrespirable airborne particulates likely to be trapped on the surface of the respiratory tract and eventually swallowed. Following are several compounds that should be considered as the agents responsible for the excess stomach and intestinal cancer.

Carbon black—Carbon blacks were introduced into the rubber industry during World War I. Three common types of carbon blacks have been used: 1) channel black (average particle diameter, 5-30 nm), 2) furnace black (30-80 nm), and 3) thermal black (120-150 nm). The furnace type is the most common. Many furnace blacks have surface-adsorbed PAH that can be extracted by organic solvents (11). Some of these adsorbed PAH have been shown to be carcinogenic and mutagenic in animals or bacterial test systems (11-15). Whereas current exposure to carbon black rarely exceeds 1 mg/m³ (mass respirable), past exposures were probably higher, inasmuch as the threshold level is 3 mg/m³ (16). In one study of workers exposed to carbon black during its production, no excesses of cancers were found (17).

Softeners, extenders, and plasticizers.—In the processing area, these substances are added to nearly all rubber compounds. Many are petroleum or coal tar products (18). Processing oils, common softeners, contain modest amounts of PAH. Other compounds used as softeners or plasticizers include coal tars, asphaltum fluxes,⁶ and petroleum-derived waxes. Coal tars have been suspected of causing a wide range of human cancers (19).

Antioxidants and accelerators.—Several of these agents are suspected of being carcinogenic on the basis of animal studies (A), of forming carcinogenic metabolites (B), or of being mutagenic in bacterial systems (C) (20-23): **antioxidants**—4-isopropoxydiphenylamine (A), *N*, *N*-diphenyl-*p*-phenylene diamine (C), PBNA (B), and **sym-2β-naphthyl-*p*-phenylene** (C); **accelerators**—2-mercaptobenzothiazole (A), *N*-oxydiethylene-2-benzothiazole (A), hexamethylenetetramine (A), and bis(dimethyldithiocarbamate)zinc (A).

Several compounds have been extensively used. For example, 1 million pounds of PBNA were used each

⁶ Asphaltum oil or fluxes are black, tarry materials obtained by partial blowing (oxidation) of still residues from the distillation of petroleum.

year. Although PBNA is metabolized to BNA, a potent bladder carcinogen (22), we found no excess bladder cancer among processing workers. It is interesting that no excess lung cancer was found in the processing area. We earlier reported an increase of respiratory morbidity among processing room workers (24).

Pancreas Cancer

The excess pancreas cancer in men who worked in elevators and in tire curing is of questionable importance. The excesses are based on relatively small numbers, and these departments do not share any common exposure.

Lung Cancer

The excess lung cancer in men who work in tire curing is based on relatively large numbers. A similar excess among curing workers has been reported (6). Curing workers in Akron had increased death rates from pneumonia (1). We also reported an increase in respiratory morbidity among current curing workers in other tire plants (25). In the curing area, the likely causal agents are the constituents of the curing fume. This fume is the result of the volatilization of the basic ingredients in the tires. The major constituents are rubber polymers, antioxidants, accelerators, and low-boiling constituents of softeners (26). The amount of PAH in the curing fume would not be great because of their high boiling points. Another possible exposure was to talc which was used to dust some types of tires. An excess of lung cancer has been reported in talc miners (27).

The excess of lung cancer in men who work in the tire molds area is small. This is a standard metal machining shop and the only likely adverse exposure is to cutting oils. Nitrosamines, which are animal carcinogens, are present in cutting oils (28). However, no excess of lung cancer was seen in a study of exposure to cutting oils (29).

The data on lung cancer in men who worked in fuel cells/deicers is unusual in that the excess was seen mainly in men who worked a relatively short time. This is not surprising, inasmuch as employment in this department occurred largely during World War II. If this is a causal association, a chlorinated organic solvent or acetylene black most likely was responsible because exposure to these agents was higher here than in other departments. In the deicer operation, acetylene black was sprayed on metal. Also, ethylene dichloride was used predominantly in these areas. This substance has been reported to be a bacterial mutagen (30).

Prostate Gland Cancer

Excesses of prostate gland cancer among all rubber workers have been reported (5, 7). The excess cases of prostate gland cancer are not likely due to a common exposure, because no apparent link exists among the departments. Machine maintenance is a standard engineering shop; the most likely causal exposure would

be to cutting oils (28). Although cadmium exposure has been reported to be associated with prostate gland cancer (31), exposure in this plant was not appreciable.

Bladder Cancer

Cancer of the urinary bladder has long been recognized as a disease of rubber workers (32). However, in one recent study of rubber workers, no excess of bladder cancer was found (5).

The excess of bladder cancer in chemical workers is relatively small. Two of the men worked only for 1 year in the chemical plant. However, two others worked for at least 15 years with the PBNA autoclave; therefore, a causal connection must be seriously considered. (A third man who worked with PBNA from 1952 to 1962 died from bladder cancer on October 6, 1976.) BNA or one of its metabolites is the substance believed to have caused bladder cancer in rubber workers in earlier studies. PBNA has been demonstrated to metabolize to BNA in the body (22).

Skin Cancer and Brain Cancer

Excesses of cancers of the skin and brain were observed among men who worked in tire assembly departments. Both types of cancers have large rate ratios: 6.5 and 4.1, respectively. Most of the skin cancers were of the basal cell or squamous types and were located predominantly on the neck and head. The skin cancer excess occurred in men who started working before 1940, whereas the brain cancer excess was present in men who started working after 1940.

Few unique exposures were noted in this area. One possibility was carbon tetrachloride, a potent animal carcinogen (33). This solvent was added to other solvents to reduce flammability. Two exposures may be related to the excess skin cancer. One is exposure to the drum resins, which contained coal tars and which have been associated with skin cancer in other industries (19). The second is exposure to the accelerator hexamethylenetetramine, a suspected animal carcinogen that has been described as a common cause of dermatitis among tire builders (21, 34).

and adhesives, particularly those for use in bonding

metal to rubber, and to some repair or patching cements. The most common solvents used in this company were refined petroleum solvents, principally highest gasoline and varnish maker's naphtha. All refined petroleum solvents are complex mixtures of hydrocarbons and contain a low percentage of benzene. Any substance responsible for the excess of leukemia or lymphatic cancer is believed to have been removed or reduced in the work environment, inasmuch as men who started work after 1945 do not have an excess rate of these diseases.

For two other reasons, we hesitate to attribute the excess of leukemia solely to benzene. First, the predominant leukemia was lymphatic. Epidemiologic evidence for an association between benzene and lymphatic leukemia is less convincing than the evidence for an association with other leukemias (36, 37). Second, one of the areas with excess leukemia deaths also has an excess of lymphosarcoma, a tumor not known to be associated with benzene.

In summary, several associations between work area and specific sites of cancer are likely to be causal. These are the association of gastrointestinal cancer with the processing area, lung cancer with curing, leukemia with extensive organic solvent exposures, and cancers of the skin and other sites with the tire assembly area. Fortunately, many of these associations no longer hold for workers who started jobs after 1940. Whether specific chemicals can be identified as having been responsible is problematic because of the complex nature of the work environment. The only realistic approach to prevention must be based on a general reduction in exposure to substances used in the manufacture of rubber products.

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