Mortality from cancer and other causes of death among synthetic rubber workers

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Abstract

Objectives—This study evaluated the mortality experience of workers from the styrene-butadiene rubber industry. Concerns about a possible association of 1,3-butadiene and styrene with lymphohaematopoietic, gastrointestinal, and lung cancers prompted the investigation.

Methods—A retrospective follow up study was conducted of 15 649 men employed for at least one year at any of eight North American styrene-butadiene rubber plants. Analyses used standardised mortality ratios (SMRs) to compare styrene-butadiene rubber workers' cause specific mortalities (1943-91) with those of the United States and Ontario general populations.

Results—On average, there were 25 years of follow up per subject. The standardised mortality ratio (SMR) was 87 (95% confidence interval (95% CI) 85 to 90) for all causes of death combined and was 93 (95% CI 87 to 99) for all cancers. There was an excess of leukaemia (SMR 131, 95% CI 97 to 174), restricted to hourly workers (SMR 143, 95% CI 104 to 191). For causes of death other than leukaemia, SMRs were close to or below the null value of 100. Results by work area (process group) were unremarkable for non-Hodgkin's lymphoma, multiple myeloma, and stomach cancer. Maintenance workers had a slight increase in deaths from lung cancer, and certain subgroups of workers had more than expected deaths from cancer of the large intestine and the larynx.

Conclusion—This study found an excess of leukaemia that is likely to be due to exposure to butadiene or to butadiene plus other chemicals. Deaths from non-Hodgkin's lymphoma, multiple myeloma, and stomach cancer did not seem to be related to occupational exposure. The excess deaths from lung cancer among maintenance workers may be due in part to confounding by smoking, which was not controlled for, and in part to an unidentified occupational exposure other than butadiene or styrene. Increases in cancer of the large intestine and larynx were based on small numbers, did not seem to be due to exposure to butadiene or styrene, and may be chance observations.

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Keywords: 1,3-butadiene; styrene; cancer

Workers in the synthetic rubber industry are exposed to numerous chemicals, with concern about toxic effects centering on 1,3-butadiene and styrene. These monomers have been used since the early 1940s to produce styrene-butadiene rubber and other polymers.

Experimental studies indicate that metabolites of butadiene are genotoxic.¹ In animals butadiene causes malignant tumours of several organs, including lymphohaematopoietic tissue, forestomach, and lung, with the effect varying considerably across species. There is also evidence that a metabolite of styrene causes carcinomas and papillomas of the forestomach in rats.²

Epidemiological studies have reported increases in leukaemia among workers exposed both to butadiene and to styrene in the styrene-butadiene rubber industry³⁻⁵ and an excess of lymphosarcoma, but not leukaemia, among workers exposed to butadiene monomer.^{6,7} There is no clear evidence that styrene causes cancer in humans.⁸⁻¹³ In 1992, the International Agency for Research on Cancer (IARC) classified butadiene as probably carcinogenic to humans (group 2A) and styrene as possibly carcinogenic to humans (group 2B).¹

This report is the third in a series describing a study of workers in the synthetic rubber industry in the United States and Canada. The first paper¹⁴ reported an excess of leukaemia among hourly workers with long duration of employment, many years since hire, and a history of employment in process groups potentially entailing relatively high exposure to butadiene. The second paper¹⁵ reported a positive association between cumulative exposure to butadiene and leukaemia. Here, we provide further data on mortality patterns, principally for causes of death other than leukaemia.

Methods

The study included men at seven of eight synthetic rubber plants previously studied by Johns Hopkins University^{3,4,16,17} and at a two plant complex previously investigated by the National Institute for Occupational Safety and Health.⁵ The maximum follow up period was 49 years (1943-91), with variable times at which the study started: 1943 (four plants), 1950 (two plants), 1960 (one plant), and 1965 (one plant). The plants were in Texas (four plants), Louisiana (two plants), Kentucky (one plant), and Ontario (one plant).

A worker was included if he had at least one year of cumulative service before 1 January 1992. Plant records and information compiled

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Table 1 Observed and expected deaths and SMRs, 1943–91, for never hourly subjects, ever hourly subjects, and the total cohort

Cause of death	Never hourly		Ever hourly		Total cohort		
	Obs	SMR	Obs	SMR	Obs/Exp	SMR	95% CI†
All causes	445	77*	3531	89*	3976/4552.8	87*	85 to 90
All cancer	104	77*	846	95	950/1023.5	93*	87 to 99
Buccal cavity and pharynx	1	27	14	53*	15/30.1	50*	28 to 82
Digestive organs	34	97	203	83*	237/278.6	85*	75 to 97
Oesophagus	0	[3.3]‡	18	66	18/30.6	59*	35 to 93
Stomach	4	72	34	76	38/50.1	76	54 to 104
Large intestine	15	122	72	94	87/89.3	97	78 to 120
Rectum	4	123	16	71	20/25.7	78	48 to 120
Liver	1	42	14	80	15/19.8	76	42 to 125
Pancreas	8	116	35	77	43/52.3	82	60 to 111
Larynx	1	54	16	124	17/14.7	115	67 to 185
Lung	30	63*	319	107	349/344.7	101	91 to 112
Skin	0	[3.7]	12	79	12/17.9	67	35 to 117
Prostate	9	94	71	100	80/80.3	100	79 to 124
Bladder	2	57	19	84	21/26.1	80	50 to 123
Kidney	5	147	18	87	23/24.0	96	61 to 144
Central nervous system	4	102	21	90	25/27.3	92	59 to 135
Lymphopoietic system	11	85	90	112	101/93.4	108	88 to 131
Leukaemia	3	60	45	143*	48/36.6	131	97 to 174
Non-Hodgkin's lymphoma	2	45	26	99	28/30.7	91	61 to 132
Hodgkin's disease	3	270	5	68	8/8.4	95	41 to 187
Multiple myeloma	3	157	11	83	14/15.2	92	50 to 155
Other lymphatic tissue§	0	[0.48]	3	146	3/2.5	122	25 to 356
Other cancer	7	61	63	84	70/86.3	81	63 to 102
Benign neoplasms	0	[1.5]	9	94	9/11.0	82	37 to 155
Allergic, endocrine, metabolic, nutritional diseases	8	76*	54	72*	62/85.3	73*	56 to 93
Mental, psychoneurotic, and personality disorders	2	49	7	21	9/37.2	24*	11 to 46
Blood diseases	1	76	11	114	12/10.9	110	57 to 192
Nervous system diseases	5	75	36	80	41/51.8	79	57 to 107
Circulatory diseases	221	80*	1739	93*	1960/2151.7	91*	87 to 95
Respiratory diseases	24	61*	188	72*	212/298.8	71*	62 to 81
Digestive diseases	23	85	104	56*	127/211.5	60*	50 to 71
Genitourinary diseases	2	27	48	76	50/71.0	70*	52 to 93
External causes	22	43*	294	76*	316/439.3	72*	64 to 80
Other specified causes	8	47*	97	67*	105/160.8	65*	53 to 79
Unknown	25	—	98	—	123	—	—

* $p < 0.05$.

†Exact confidence interval.

‡Expected deaths.

§Observed numbers include two decedents with myelofibrosis and one with polycythaemia vera among ever hourly subjects.

during previous epidemiological investigations identified 15 469 eligible subjects.

All jobs in the styrene-butadiene rubber industry held by subjects were aggregated into 8281 unique work area-job groups (work area groups). Work area groups were combined into five main process groups and seven process subgroups (see table 4). Jobs at two plants could not be accommodated into the subgroup classification because specific work area information was lacking. Potential exposure to monomers varied by process group and subgroup.^{14 15}

The vital status of subjects was determined from plant records and from linkages with the Social Security Administration's death master file, national death index, divisions of motor vehicles of Texas, Louisiana, and Kentucky, and the Canadian mortality data base. Underlying cause of death information came from death certificates, available for 96% of 3397 United States and for all Canadian decedents, and was coded for analysis with the eighth revision of the international classification of diseases (ICD-8) and the coding rules in effect at the time of death.

Analyses compared subjects' mortalities with general population rates, with the standardised mortality ratio (SMR) as the measure of association. We obtained expected numbers of deaths by multiplying the race, age, and calendar time specific mortalities of the United States male general population¹⁸ or of the

Ontario male population (data furnished by Statistics Canada) by the corresponding number of person-years of follow up of the cohort and summing across all stratifying variables. Follow up began one year after hire, on the first day of work in a specific process group or subgroup, or on the plant specific follow up start date, whichever was latest, and ended on 1 January 1992, on the date of death, or on the date of loss to follow up, whichever was earliest. 95% Confidence intervals (95% CIs) of the SMRs were computed under the assumption that the observed numbers of deaths follow a Poisson distribution.

Selected analyses compared the rates of subjects from each United States plant with the male general population rates of the state where the plant was.¹⁹ The results obtained with state rates were similar to results based on United States rates, and we report only the United States rates except where noted.

Results

Of the 15 649 men included in the study, 13 586 (87%) were white and 2063 (13%) were black. Of the white men, 11 460 (84%) had worked in an hourly job, and 2116 (16%) had never been hourly. Of the black men, 2032 (98%) were ever hourly, and 31 (2%) were never hourly. About 50% of the subjects were hired before 1960, 44% had worked for at least 10 years (median, 7.8 years), and 59% started

Table 2 Observed and expected deaths and SMRs, 1943–91, for ever hourly subjects with ≥ 10 years worked and ≥ 20 years since hire, according to race

Cause of death	≥ 10 worked and ≥ 20 since hire						
	White		Black		Overall		
	Obs	SMR	Obs	SMR	Obs/Exp	SMR	95% CI†
All causes of death	1239	98	252	85*	1491/1561.4	95	91 to 100
All cancer	308	96	72	98	380/394.8	96	87 to 106
Buccal cavity and pharynx	7	83	0	[2.6]‡	7/11.0	64	26 to 131
Digestive organs	59	71*	21	101	80/104.0	77*	61 to 96
Oesophagus	6	74	1	23	7/12.3	57	23 to 117
Stomach	7	56	3	72	10/16.6	60	29 to 111
Large intestine	23	77	12	231*	35/35.1	100	69 to 139
Rectum	5	66	0	[1.2]	5/8.7	57	19 to 134
Liver	3	55	1	63	4/7.0	57	15 to 145
Pancreas	11	67	3	81	14/20.0	70	38 to 117
Larynx	9	207	0	[1.3]	9/5.7	159	73 to 302
Lung	115	99	26	105	141/140.5	100	84 to 118
Skin	5	92	0	[0.4]	5/5.9	85	28 to 199
Prostate	26	99	9	98	35/35.5	99	69 to 137
Bladder	9	100	1	82	10/10.2	98	47 to 181
Kidney	7	89	1	88	8/9.0	89	39 to 176
Central nervous system	11	143	0	[0.7]	11/8.4	131	65 to 235
Lymphopoietic system	38	136	11	241*	49/32.5	151*	112 to 200
Leukaemia	21	192*	7	436*	28/12.5	224*	149 to 323
Non-Hodgkin's lymphoma	13	133	2	172	15/11.0	137	77 to 226
Hodgkin's disease	1	72	0	[0.2]	1/1.6	63	2 to 348
Multiple myeloma	3	62	2	132	5/6.3	79	26 to 185
Other lymphatic tissue§	0	[1.0]	0	[0.1]	0/1.1	0	0 to 348
Other cancer	22	86	3	45	25/32.2	78	50 to 115
Benign neoplasms	5	181	0	[0.7]	5/3.4	146	47 to 340
Allergic, endocrine, metabolic, nutritional diseases	24	100	11	145	35/31.6	111	77 to 154
Mental, psychoneurotic, and personality disorders	4	48	1	30	5/11.8	42*	14 to 99
Blood diseases	3	108	2	271	5/3.5	142	46 to 331
Nervous system diseases	10	67	2	77	12/17.5	69	35 to 120
Circulatory diseases	645	102	128	94	773/768.8	101	94 to 108
Respiratory diseases	93	96	8	43*	101/116.1	87	71 to 106
Digestive diseases	36	68*	6	47	42/66.0	64*	46 to 86
Genitourinary diseases	20	129	5	71	25/22.5	111	72 to 164
External causes	58	92	8	44*	66/81.1	81	63 to 104
Other specified causes	30	99	4	28	32/44.3	72	49 to 102
Unknown cause	3	—	5	—	8	—	—

* $p < 0.05$.

†Exact confidence interval.

‡Expected deaths.

§Observed number includes one decedent with myelofibrosis.

work before the age of 30. Black men had worked longer than white (median, 12 *v* 7.3 years).

Subjects had a total of 386 172 person-years of follow up, an average of 24.7 years per subject. At the end of follow up, 3976 (25%) subjects were dead, 10 939 (70%) were presumed living, and 734 (5%) were lost to follow up.

For the total cohort the SMR for all causes of death combined was 87 (95% CI 85 to 90), based on 3976 observed and 4553 expected deaths (table 1). For all cancers, the SMR was 93 (950 observed/1024 expected; 95% CI 87 to 99). For each cause of death category other

than leukaemia (SMR 131), the SMR was close to or below the null value of 100. Differences between observed and expected numbers of deaths were negligible for non-Hodgkin's lymphoma (28/31, SMR 91), Hodgkin's disease (8/8.4, SMR 95), multiple myeloma (14/15, SMR 92), and other lymphatic tissue cancer (3/2.5, SMR 122). SMRs for all digestive cancer, for stomach cancer, and for lung cancer were 85, 76, and 101, respectively. Results for ever hourly subjects were similar to results for the overall cohort. Never hourly subjects had lower than expected mortality from most causes of death; their SMR was imprecisely increased for multiple myeloma and Hodgkin's disease and was below the null for non-Hodgkin's lymphoma.

Among ever hourly subjects with both a relatively long duration of employment (≥ 10 years) and a long period since hire (≥ 20 years), increases occurred for cancers of the large intestine (black men only: 12/5.2, SMR 231, 95% CI 119 to 402), larynx (white men only: 9/4.4, SMR 207, 95% CI 95 to 393), central nervous system (white men only: 11/7.7, SMR 143, 95% CI 71 to 256), and non-Hodgkin's lymphoma (15/11, SMR 137, 95% CI 77 to 226, table 2). Lung cancer SMRs approximated to the null value of 100 for both white and black men.

In further analyses of hourly subjects' cause specific mortalities by race, period of death,

Table 3 Observed and expected deaths for cancer of the large intestine and lung among ever hourly men according to selected characteristics

	Large intestine			Lung		
	White Obs/Exp	Black Obs/Exp	Total Obs/Exp	White Obs/Exp	Black Obs/Exp	Total Obs/Exp
Total:	58/66	14/11	72/77	256/247	63/50	319/297
Year of death:						
<1975	17/20	1/3.6	18/24	61/68	10/15	71/83
1975–84	21/24	6/3.6	27/27	112/92*	21/18	133/110
≥ 1985	20/22	7/3.7	27/26	83/87	32/17*	115/105
Years since hire, years worked:						
<20, <10	7/9.3	0/1.4	7/11	29/30	5/5.4	34/36
<20, ≥ 10	5/5.4	0/1.0	5/6.4	21/21	5/5.5	26/27
≥ 20 , <10	23/22	2/3.2	25/25	90/80	27/14*	117/95
≥ 20 , ≥ 10	23/30	12/5.2*	35/35	115/116	26/25	141/141
Year of hire:						
<1950	27/37	5/6.3	32/43	129/124	32/24	161/148
1950–59	23/21	6/3.6	29/25	80/87	23/20	103/107
≥ 1960	8/8.7	3/1.0	11/9.7	47/37	8/5.7	55/42

* $p < 0.05$.

Table 4 Observed and expected deaths for selected cancers by process group, subjects from six plants

	Subjects	Person-years	All cancer Obs/Exp	Non-Hodgkin's lymphoma Obs/Exp	Multiple Myeloma Obs/Exp	Large intestine cancer Obs/Exp	Lung cancer Obs/Exp	Larynx cancer Obs/Exp
Rubber/BD production	5654	140 769	311/335	9/11	4/6.3	35/30	102/116	10/4.8
Polymerisation	2418	58 097	146/167	6/5.3	0/3.1	11/15	42/58*	5/2.4
Coagulation	1059	25 763	61/81*	2/2.6	0/1.3	10/7.0	16/29*	2/1.2
Finishing	4314	101 784	189/215	5/7.1	1/3.8	19/18	68/75	7/3.1
Maintenance	3850	92 297	319/303	11/9.4	3/5.2	28/27	129/104*	7/4.3
Shop	1073	26 214	90/85	2/2.7	1/1.3	9/7.7	38/29	1/1.2
Field	3015	71 312	252/234	9/7.2	1/4.2	21/21	102/80*	6/3.3
Labour	2629	55 304	237/237	3/5.8	7/5.0	21/18	84/77	1/4.1
Production	691	15 042	80/77	2/1.8	4/1.7	5/5.7	25/25	0/1.3
Maintenance	1921	38 067	157/163	3/3.9	4/3.2	12/12	57/54	2/2.7
Laboratories	1422	35 663	50/60	1/2.1	0/1.1	5/4.9	15/21	0/0.9
Other operations	2342	57 921	158/173	3/5.3	2/3.0	11/15	54/59	7/2.6*

*p<0.05.

duration by employment, years since hire, and year of hire, mortality patterns were unremarkable for non-Hodgkin's lymphoma, multiple myeloma, laryngeal cancer, and cancer of the central nervous system. The excess of cancer of the large intestine among black men was concentrated in groups followed up in or after 1975 (13/7.3) and hired in or after 1950 (9/4.6, table 3), as well as being restricted to the subgroup with ≥ 10 years of employment and ≥ 20 years since hire (12/5.2). Among white men, the observed number of deaths from cancer of the large intestine was similar to the expected number in all subgroups examined.

Increased lung cancer occurred among white ever hourly men in 1975–84 and among black men in 1985 and later and was limited to subjects with ≥ 20 years since hire and < 10 years of employment (117/95, table 3). Black men with < 10 years of employment had more deaths than expected from lung cancer at five of the seven United States plants; however, the absolute differences between the observed and expected numbers at each plant were small, ranging from 0.5 to 4.5. Results of analyses with rates from the state general population for comparison with the United States component of the cohort indicated that lung cancer SMRs based on state rates were closer to the null value, and increased SMRs were about 10% lower than those based on United States rates. However, the SMR remained increased among black men with < 10 years worked and ≥ 20 years since hire (27/16, SMR 167, 95% CI 110 to 243).

Process group analyses did not yield any striking results for all cancer combined, non-Hodgkin's lymphoma, or multiple myeloma (table 4). Results were roughly null for polymerisation, maintenance labour, and laboratory process groups that have relatively high exposure to monomers, especially butadiene.

For the overall cohort of black and white men combined, no process group or subgroup had a considerable increase or deficit deaths from cancer of the large intestine (table 4). Black men in production had six observed compared with 1.7 expected deaths from cancer of the large intestine (SMR 348, 95% CI 127 to 758); four of the six men had worked in finishing and two had worked in unspecified production areas. There were no observed deaths among black men in polymerisation (expected, 0.44) or laboratories (expected,

0.28). The difference between observed and expected deaths among black men in maintenance labour was minor (8/7.2).

Of the 12 black men with ≥ 10 years worked and ≥ 20 years since hire, seven had worked in maintenance labour (7/4.0, SMR 175, 95% CI 70 to 360). The remaining five had worked in several process groups or subgroups other than maintenance labour, polymerisation, and laboratories (5/1.2, SMR 417, 95% CI 135 to 972).

Stomach cancer was not associated with any process group or subgroups. Observed/expected numbers were 3/7.1 for polymerisation, 5/9.8 for maintenance labour, and 3/2.4 for laboratories.

Maintenance workers had a small increase in deaths from lung cancer (129/104, SMR 124, 95% CI 103 to 147). This increase was present among both white and black men, in both shop and field maintenance workers, and in both short and long term maintenance workers (table 4).

Laryngeal cancer SMRs were increased for production workers (10/4.8, SMR 208, 95% CI 100 to 382), maintenance workers (7/4.3, SMR 164, 95% CI 66 to 337), and workers in other operations (7/2.6, SMR 276, 95% CI 111 to 568). All decedents from laryngeal cancer in each of these three process groups also had worked in one or both of the other two groups. There were 3/1.4 deaths from laryngeal cancer among subjects ever in finishing and never in polymerisation, whereas polymerisation workers who had never been in finishing had about equal observed and expected numbers of deaths (1/1.0). Among maintenance workers, the increase was limited to those in field maintenance, but this result was based on small numbers.

Discussion

The overall cohort and the subgroups of white and black subjects had small deficits, about 5%–10%, of deaths from all causes combined, from all cancers, and from circulatory diseases. The study found a positive association between employment in the styrene-butadiene rubber industry and leukaemia. Other results include essentially null associations between employment in the styrene-butadiene rubber industry and mortality from non-Hodgkin's lymphoma and multiple myeloma. Although slight increases in these forms of cancer were present in some subgroups, there was no consistent

pattern by duration of employment, time since hire, period of hire, or process group. No consistent excess of these cancers occurred in process groups and subgroups, such as laboratories, polymerisation, and maintenance labour, entailing potentially high exposure to butadiene or styrene. Such patterns, in contrast, were found for leukaemia.¹⁴

Our evaluation of the relation between employment in the styrene-butadiene rubber industry and non-Hodgkin's lymphoma is limited by our reliance on death certificates to identify cases. Because survival rates after a diagnosis of non-Hodgkin's lymphoma are high (mean five year survival is 48% for men diagnosed in 1974–89²⁰), mortality may not be an optimal end point for the study of this form of cancer. Non-Hodgkin's lymphoma may, in later clinical stages, transform into leukaemia, and leukaemia, not non-Hodgkin's lymphoma, may be recorded on the death certificate. The above problems could obscure the relation between employment in the styrene-butadiene rubber industry and non-Hodgkin's lymphoma.

A population based case-control study of non-Hodgkin's lymphoma found no association between it and work in the styrene-butadiene industry.²¹ Other studies of styrene-butadiene rubber and butadiene production workers have not reported results for non-Hodgkin's lymphoma or multiple myeloma separately. Results were presented only for lymphosarcoma, a type of non-Hodgkin's lymphoma, and for other lymphohaematopoietic cancer, a category that includes both non-Hodgkin's lymphoma and multiple myeloma. Matanoski *et al*¹⁷ found no association between work related to the styrene-butadiene rubber industry and lymphosarcoma. Although one study of styrene-butadiene rubber workers⁵ and two studies of butadiene production workers^{6,7} reported an excess of deaths from lymphosarcoma, there was no persuasive evidence of a dose-response trend or of an induction time effect. Cowles *et al*²² found no deaths from lymphohaematopoietic cancer in their study of butadiene production workers.

In the present study, cancer of the large intestine was the only cancer of the digestive tract for which increased mortality was found in some subgroups. The increase was restricted mainly to black ever hourly men with long employment and long potential induction time. However, the finding of an increase both among maintenance labourers and among workers in process groups or subgroups that did not entail high exposure to butadiene or styrene suggests that exposures to monomers were not responsible. Other studies with information on cancer of the large intestine have not reported an excess.^{6,17,21}

Lung cancer increases were found in maintenance workers. This pattern may be due in part to confounding by smoking, a possibility we did not evaluate, and in part to an unidentified occupational exposure other than butadiene and styrene. Several features are consistent with the presence of confounding, including the weakness of the association, the absence of

a clear positive relation with duration of employment, the absence of a trend with increasing time since hire, and the attenuated strength of associations when state, rather than national, lung cancer rates were used for comparison. Asbestos is a lung carcinogen that may have been present at some of the study plants, an interpretation suggested by the finding of nine deaths from mesothelioma among ever hourly subjects (seven in maintenance) employed in operations related to styrene-butadiene rubber in the present study. Our results for lung cancer differ from most earlier studies of styrene-butadiene rubber industry and butadiene production workers, which reported fewer than expected deaths.^{5,6,17,20}

The increase in deaths from laryngeal cancer found among certain subgroups of subjects in the present study is difficult to interpret. The deaths occurred only among white subjects, and the excess was not clearly associated with any process group. All results for laryngeal cancer were statistically imprecise. Matanoski *et al*¹⁷ reported an increase, based on two observed deaths, among utility workers. In our study, utility workers were incorporated into the other operations category, and we found a slight increase in these workers. Utility workers are employed in power generation and in water supply and treatment operations and would have had low exposure to monomers. Meinhardt *et al*⁶ and Cowles *et al*²² did not provide data on laryngeal cancer. Divine *et al*⁶ found slightly more than expected deaths from laryngeal cancer in some subgroups of butadiene production plant workers, but the results were based on small numbers.

In summary, this study found an excess of leukaemia that may be due to occupational exposure to butadiene or a combination of butadiene and styrene.^{14,15} Other results include essentially null relations between employment in the styrene-butadiene rubber industry and mortality from non-Hodgkin's lymphoma, multiple myeloma, and stomach cancer. Slight increases in deaths from lung cancer among maintenance workers may be attributable in part to confounding by smoking and in part to an unidentified occupational exposure. Lung cancer does not seem to be related to exposure to butadiene or styrene. Certain subgroups of the cohort had more than the expected deaths from laryngeal cancer and from cancer of the large intestine. These increases did not seem to be due to exposure to butadiene or styrene and probably are chance findings.

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