Mortality Analysis of Workers
Exposed to Chloroprene

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INTRODUCTION

A historical cohort mortality study of 1,575 men occupationally exposed to chloroprene was conducted by the medical divison of E.I. du Pont de Nemours and Company (Du Pont). The study was designed to evaluate the risk of lung cancer and other major causes of mortality with respect to chloroprene exposure. The study showed no association between chloroprene exposure and an increased risk of mortality from specific diseases, including lung cancer (Pell, 1978).

The National Institute for Occupational Safety and Health (NIOSH) assisted Du Pont in the study by providing additional epidemiologic resources. NIOSH was able to determine the vital status of 223 of 240 men in the cohort who could not be located by Du Pont. This effort reduced the percentage of men lost to follow-up from 15.2% to 1.1%. Once the original study was completed, NIOSH was given the data by Du Pont to reanalyze, using the NIOSH modified life table computer program. This report summarizes the results of the reanalysis.

DISCLAIMER

Because NIOSH was involved neither in the identification of the cohort nor in the extraction of data from Du Pont personnel files, the agency cannot attest to the accuracy or completeness of the data upon which the study was based.

PLANT HISTORY

The Du Pont plant is located in Louisville, Kentucky and has manufactured neoprene rubber from chloroprene, a chlorinated hydrocarbon monomer, since the plant began operation in 1942. The plant began production of synthetic rubber as a result of government effort to provide a substitute for natural rubber needed for the war efforts. In 1949, the plant was acquired by Du Pont. In addition to producing neoprene rubber, the plant manufactured chloroprene from acetylene between 1942 and 1973. Since 1973 chloroprene has been made from butadiene, but at other Du Pont plants. Presently, crude chloroprene is shipped to the Louisville plant where it is purified and polymerized to produce neoprene rubber.

METHODS

The cohort, as defined by Du Pont, included all 1,575 male hourly employees who were working at the Louisville plant on June 30, 1957. Potential cohort members were identified via the plant's 1957 employment roster. The plant's 1957 roster was selected for three reasons: 1) Du Pont began its cancer epidemiological surveillance program in 1956, 2) the plant's workforce was relatively stable at that point in time, and 3) most members of the cohort had at least 15 years of potential exposure to chloroprene. Salaried and female employees were excluded by Du Pont, because most had minimal or no potential exposure to chloroprene.

Demographic and work history data for each member of the cohort were compiled by Du Pont. NIOSH was given a computer tape containing the following data for each cohort member: employee identification number, sex, date of birth, date of death or date last observed, underlying cause of death, detailed work history, and occupational exposure levels. The racial distribution of the cohort was unknown, but was thought to be 90% white. However, for this analysis, all cohort members were assumed to be white. The detailed work history consisted of specific work periods and job titles. Each job within the plant was assigned a relative exposure level, i.e., "high", "moderate", "low", or "varied" in potential for exposure to chloroprene, due to the limited industrial hygiene data for airborne concentrations of chloroprene in the plant from 1942 to 1970 (Table 1). This classification was based upon the degree of chloroprene exposure that was presumed to accompany a specific job within the plant and was developed by an industrial hygienist who worked at the Louisville plant for 25 years.

The cohort was followed from June 30, 1957 to December 31, 1974. The vital status of the cohort was ascertained using Du Pont personnel records and data from the Social Security Administration, state departments of motor vehicle registration, and state departments of vital statistics. The vital status of 1,559 (or 98.9%) of the 1,575 men in the cohort was determined (Table 2).

The date and underlying cause of death were obtained from death certificates for each of the 193 deaths in the cohort. The causes of death were coded

according to the rules of the International Classification of Diseases (ICD) in effect at the time of death, and, for this analysis, were converted to seventh revision codes.

A modified life table computer program was used to calculate the number of person-years at risk (PYAR), stratified by five-year age and calendar periods. For the total cohort, the number of PYAR contributed by each cohort member was the number of years from June 30, 1957 to the date of death or to the study end date (December 31, 1974) for those alive on that date. Men lost to follow-up were assumed to be alive as of the study end date. The expected number of deaths for each cause was calculated by multiplying the PYAR by United States white male mortality rates specific for five-year age and calendar periods. The standardized mortality ratio (SMR)* was calculated for selected causes of death. Differences between the observed and expected numbers of deaths were tested for statistical significance, assuming a Poisson distribution. If the observed number of deaths was greater than two, an exact p-value was calculated using a two-sided test and 95% confidence limits were computed for the SMR (Rothman and Boice, 1979).

The total cohort was divided into two groups based upon the degree of chloroprene exposure. One group, which will be referred to as the "high exposure" subcohort, contained all workers who were ever exposed to a high

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*SMR = $\frac{\text{observed number of deaths}}{\text{expected number of deaths}}$ X 100

level of chloroprene and the other group, known as the "low exposure" subcohort, consisted of workers who were exposed only to moderate, low, or varied levels of chloroprene. If a worker held more than one job, his exposure classification for this analysis was the highest level associated with any of the jobs that he held during his work experience at the plant.

The "high exposure" subcohort was further divided into one of three job categories: chemical operators, maintenance mechanics, or other high exposure occupations (Appendix A). The latter category included clean-up operators, helpers, poly unit mechanics, and process mechanics. Men with multiple high exposure jobs, e.g., chemical operator and maintenance mechanic, were not restricted to only one high exposure job category. In fact, each high exposure job category contained all the workers who had ever worked at the specific job(s) listed for that particular category.

In the exposure-specific analysis, a worker potentially exposed to a high level of chloroprene did not accumulate PYAR until he worked at a high exposure job. Then, PYAR contributed to the "high exposure" subcohort were calculated from the first day of high exposure and not from the first day of follow-up (June 30, 1957), if the first high exposure occurred after June 30, 1957 (Figure 1, example 1). If a worker was exposed to a high level of chloroprene before mid-1957, he did not begin contributing PYAR to the "high exposure" subcohort until June 30, 1957 (Figure 1, example 2). A worker who was exposed only to moderate, low, or varied levels of chloroprene began contributing PYAR to the "low exposure" subcohort on June 30, 1957 or the

first day of chloroprene exposure, whichever occurred later. If a worker was originally exposed to moderate, low, or varied levels and then to a high level of chloroprene, he contributed PYAR to the "low exposure" subcohort until he was exposed to a high level of chloroprene (Figure 1, example 3). Once he was exposed to a high level, he then provided PYAR to the "high exposure" subcohort for the remainder of the follow-up period and regardless of subsequent chloroprene exposure jobs (Figure 1, example 1).

Cancer mortality data were analyzed with respect to latency and duration of chloroprene exposure. Latency was defined as the interval from onset of chloroprene exposure. For the total cohort and the "low exposure" subcohort, latency began at the first day of exposure to chloroprene. For the "high exposure" subcohort, latency began for a worker when he was exposed to a high level of chloroprene. The observed and expected numbers of deaths due to malignant neoplasms of the major organ systems were stratified by 10-year intervals of latency and by 10-year intervals of chloroprene exposure. A chi-square test for trend, with one degree of freedom, was used to test for linear associations between SMRs and latency or duration of exposure (Breslow, 1981).

RESULTS

Of the 1,575 men in the total cohort, 851 were allocated to the "high exposure" subcohort and 823 were assigned to the "low exposure" subcohort. The 851 high exposed workers included 457 chemical operators, 372 maintenance mechanics, and 158 men who held other high exposure occupations at the Louisville plant. The total number of workers in the "high exposure" subcohort did not equal the sum for the specific high exposure occupations, because as mentioned earlier, a worker could be in more than one high exposure job category. A total of 99 workers contributed PYAR to the "low exposure" subcohort and subsequently to the "high exposure" subcohort and these workers were included in both subcohorts. In addition, workers in the total cohort accumulated a total of 26,304 PYAR during 1957-1974, or an average of 16.7 PYAR per cohort member. Workers in other exposure-specific categories accumulated fewer PYAR on the average per cohort member (Table 3).

The men in the total cohort were 29.4 years old (95% confidence limits=29.0 and 29.7) when first exposed to chloroprene at the Louisville plant. Those in the "high exposure" subcohort were slightly older ($\bar{x}$=30.8 years, 95% c.l.=30.3 and 31.4), whereas those in the "low exposure" subcohort were approximately the same age ($\bar{x}$=29.5, 95% c.l.=29.1 and 30.0) as the total cohort upon first exposure to chloroprene. Chemical operators were 29.0 years old (95% c.l.=29.1 and 30.0) when they were first assigned to high exposure jobs. Both maintenance mechanics and workers in other high

exposure occupations were older, 34.2 years (95% c.l.=33.4 and 34.9) and 31.4 years (95% c.l.=30.0 and 32.7), respectively (Table 4).

In the total cohort, 193 deaths occurred among workers exposed to chloroprene in contrast to 244.9 expected deaths (table 5). The difference was statistically significant (p=.0006). There were nonsignificant excesses in observed deaths compared to expected deaths from malignant neoplasms of the digestive system (19 observed deaths versus 13.1 expected, p=.14), respiratory system (19* versus 17.0, p=.69), and lymphatic/hematopoietic system (7 versus 5.0, p=.47). A statistically significant excess number of deaths was found for malignant neoplasm of the biliary passages and liver (4 versus 0.7, p=.01). Deaths due to diseases of the circulatory system (80 versus 109.1, p=.004) were significantly less than expected, but deaths due to vascular lesions affecting the central nervous system (18 versus 13.3, p=.25) revealed a nonsignificant excess.

Fewer total deaths occurred than expected among workers in the "high exposure" subcohort (91 versus 120.8, p=.006) and among those in the "low exposure" subcohort (102 versus 124.0, p=.04) (tables 6-7). As seen in

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*Clinical reports obtained by Du Pont only confirmed 18 of 19 respiratory cancer deaths. Du Pont believes that one death certificate was incorrectly coded as lung cancer, since the clinical report indicated that the tumor metastasized from the bladder to the lungs.

the total cohort, both subcohorts revealed nonsignificant excesses in observed deaths from malignant neoplasms of the digestive, respiratory, and lymphatic/hematopoietic systems. Three of the four deaths from malignant neoplasm of the biliary passages and liver (3 versus 0.4, p=.01) occurred among workers in the "high exposure" subcohort. Both subcohorts had fewer deaths than expected from diseases of the circulatory system; however, workers in the "low exposure" subcohort had more deaths than expected from vascular lesions affecting the central nervous system (15 versus 6.9, p=.01).

Mortality among men who worked as chemical operators, maintenance mechanics, and other high exposure occupations is reported in tables 8-10. There were 31 deaths compared to 44.1 expected (p=.04) among chemical operators, of which eight were due to malignant neoplasms (8 versus 8.2, p=.99). There were 45 deaths among maintenance mechanics which were significantly less than the expected number of 64.4 (p=.01). Twelve of the 45 deaths resulted from malignant neoplasms (12 versus 12.7, p=.99), and this included three deaths from malignant neoplasm of the biliary passages and liver (3 versus 0.2, p=.002). All three deaths from malignant neoplasm of the liver and biliary passages occurred after 10 to 19 years of chloroprene exposure. One death, occurring after 10 to 19 years of latency, was from malignant neoplasm of the liver (ICD 155.0), and the other two deaths, occurring after 20 years of latency, were due to malignant neoplasm of the gallbladder (ICD 155.1). Pathology reports were not available for either of the two latter decedents to verify the primary tumor site. There were 16 deaths in contrast to 19.8 expected (p=.47) among men who had other high

exposure occupations, and only five deaths due to malignant neoplasms (5 versus 3.9, p=.70) were reported. All three occupational groups had fewer deaths than expected from diseases of the circulatory system. Other specific causes of death were observed, but the numbers were too small to be meaningful.

The observed and expected numbers of deaths from malignant neoplasms among workers with less than 10 years, 10 to 20 years, and 20 or more years of latency are presented in tables 11-16. There were no statistically significant trends with respect to latency. The observed and expected numbers of deaths from malignant neoplasms among workers with less than 10 years, 10 to 20 years, and 20 or more years of presumed chloroprene exposure are shown in tables 17-22. Again, no statistically significant trends were apparent among the SMRs.

DISCUSSION

As expected with an industrial population, mortality from all causes and from diseases of the circulatory system among workers exposed to chloroprene was significantly less than expected when compared to the United States population. This decrease in mortality from all causes was observed in the total cohort, "high exposure" subcohort, "low exposure" subcohort, and among chemical operators and maintenance mechanics, and a similar pattern from diseases of the circulatory system was seen in the total cohort and "low exposure" subcohort. This favorable mortality experience for the cohort probably reflects the "healthy worker" effect (Fox and Collier, 1976; McMichael, 1976).

Within the total cohort and within both subcohorts, nonsignificant excesses were seen for malignant neoplasms of three organ systems: digestive, respiratory, and lymphatic/hematopoietic. The nonsignificant excesses for the three organ systems were present after 20 years of latency. However, no statistically significant trends were evident, but this may have been due to the small numbers in the strata. A statistically significant two-fold excess in mortality from vascular lesions affecting the central nervous system was seen among workers in the "low exposure" subcohort, but it is uncertain whether this excess is related to chloroprene exposure.

Data analysis by type of occupation, i.e., chemical operators, maintenance mechanics, and other high exposure occupations, did not show a significant

excess in mortality among workers who held high exposure jobs. There was one exception; an excess for maintenance mechanics dying from malignant neoplasm of the biliary passages and liver. As stated earlier, two of the deaths were due to malignant neoplasm of the gallbladder and the other was attributed to malignant neoplasm of the liver. No gallbladder carcinogen has yet been identified in humans (Diehl, 1980). However, two studies have suggested a higher risk of mortality from malignant neoplasm of the gallbladder among other occupational groups, including workers in textile manufacturing, metal fabricating, automobile manufacturing, and rubber processing (Krain, 1972; Mancuso and Brennan, 1970).

Other factors that were considered were the cohort selection criteria and the statistical power. In this study, the cohort was selected from a roster of employees at the Louisville plant on June 30, 1957. As stated earlier, this year was chosen for three reasons: 1) Du Pont began its cancer epidemiological surveillance program in 1956, 2) the plant's workforce was relatively stable at that point in time, and 3) most members of the cohort had at least 15 years of potential exposure to chloroprene. Although the employee roster provided an excellent means of identifying all employees working at a plant in a specific year, it excluded all employees who were exposed to chloroprene, but who terminated before June 30, 1957. If the cohort had included these terminated employees, this would had increased the size of the cohort and, in turn, would have resulted in more PYAR, larger numbers of expected deaths, and greater statistical power.

Power values based on the equation by Beaumont and Breslow (1981) were calculated for selected causes of death for the total cohort. The power values indicated a 87% chance of detecting a risk ratio of 1.5 for all malignant neoplasms, if an excess risk actually existed. However, the chance of detecting the same risk ratio for more specific causes of death was considerably less. For example, there was only a 37% and 46% chance of detecting a risk ratio of 1.5 for malignant neoplasms of the digestive system and respiratory system, respectively. Of course, the power increases with larger risk ratios, and it appears that the total cohort had a power of 80% or more to detect a risk ratio of two or more for some of the major causes of death, e.g., malignant neoplasm of the respiratory system. However, the power is reduced well below an acceptable level of 80% when the total cohort is stratified by the degree of exposure or by type of occupation. Thus, the nonsignificant excesses in mortality found in the study may have been the result of small statistical power.

In conclusion, the results in this study appear to agree with those presented by Du Pont and fail to support the hypothesis that men occupationally exposed to chloroprene are at a higher risk of dying from lung cancer or other specific diseases than the general population. However, these results are based on data from a cohort that may have been affected by cohort selection factors and by small statistical power.

RECOMMENDATIONS

Recommendations for further work on this study are 1) to expand the period of follow-up from December 31, 1974 to the present and 2) to include chloroprene-exposed workers at the plant who terminated or died before June 30, 1957. Additional follow-up will increase the number of PYAR and, in turn, the statistical power of the study for specific causes of death. In addition, a modification of the cohort selection criteria would allow for the entry of employees who were hired before June 30, 1957 and who were potentially exposed to higher levels of chloroprene. However, due to the high turnover rate in the 1940's, it is recommended that only individuals with one or more years of employment at the plant be included in the cohort in order to keep follow-up costs at a minimum.

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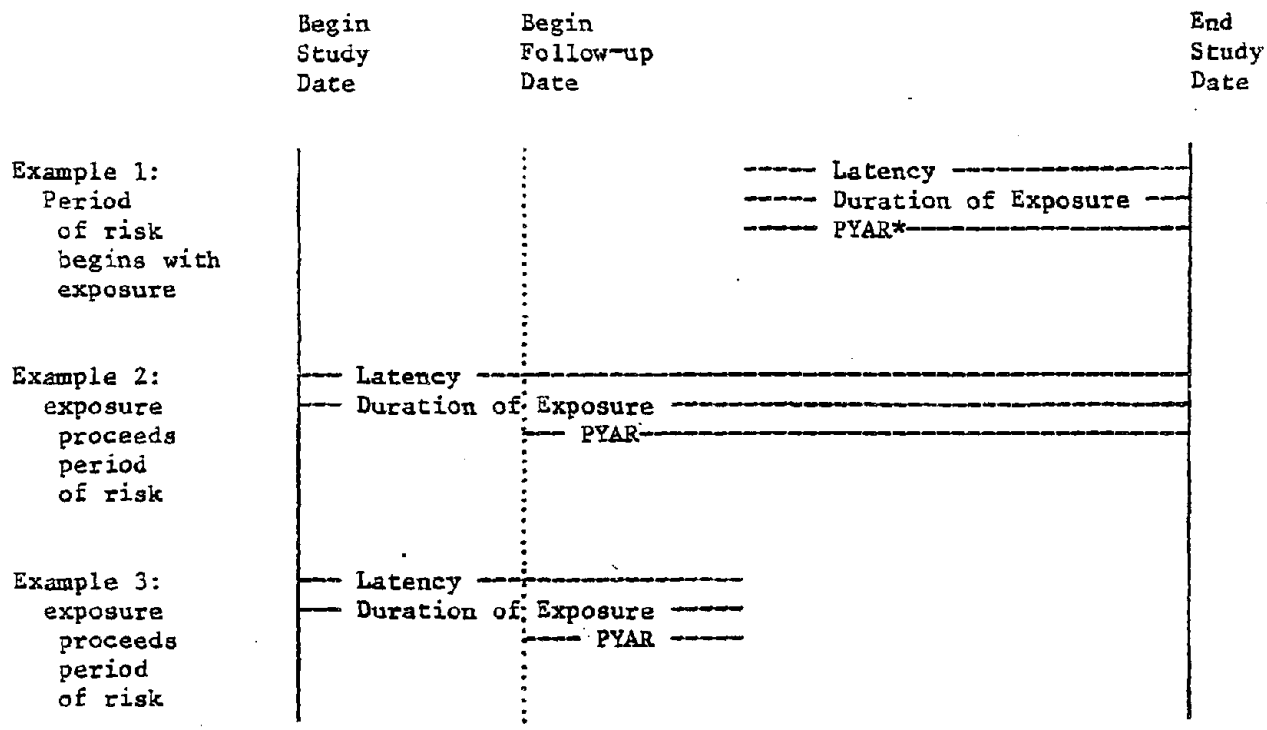
Figure 1

Examples of the Distribution of Person-Years at Risk
With Respect to Latency and Duration of Exposure



*PYAR = person-years at risk

Table 1

Chloroprene Mortality Study
Classification of Level of Exposure to Chloroprene in Louisville Works Cohort:
Representative Occupations

High Exposure

Chemical operator (monomer and polymer)
Clean-up operator
Helper
Poly unit mechanic
Process mechanic
Maintenance mechanic

Moderate Exposure

Chemical operator, monovinylacetylene
Laboratory technician
Machinist
Pump mechanic
Laboratory dishwasher
Shop mechanic

Low or No Exposure

Bagger
Cafeteria worker
Clerk
Guard
Hydrogen chloride operator
Incinerator operator
Power operator
Stores attendant
Tool room attendant
Truck driver
Bag handler
Cook
Counter attendant
Print machine operator
Shipping helper

Varied Exposure

Electrician
Instrument mechanic
Janitor
Lagger
Millwright
Painter
Pipefitter
Rigger
Mechanic

Reference: Pell S: Mortality of Workers Exposed to Chloroprene. Journal of Occupational Medicine 20(1): 21-29, 1978

Table 2

Chloroprene Mortality Study
Vital Status of the Cohort as of December 31, 1974

Alive	1,365	(86.7%)
Deceased	193	(12.2%)
Lost to follow-up	17	(1.1%)
Total	1,575	(100.0%)

Table 3

Chloroprene Mortality Study
Number of Men, Person-Years at Risk,
and Average Person-Years at Risk per Cohort Member
For the Total Cohort and Specific Exposure Categories,
1957-1974

	Number of Men	Person-Years at Risk (PYAR)	Average PYAR per Cohort Member
Total Cohort	1575	26,304	16.7
"High Exposure" Subcohort	851	13,606	16.0
Chemical Operators	457	7,174	15.7
Maintenance Mechanics	372	5,694	15.3
Other High Exposure Occupations	158	1,918	12.1
"Low Exposure" Subcohort	823	12,644	15.4

Table 4

Chloroprene Mortality Study
Age Distribution of the Total Cohort and Specific Exposure Categories
At First Exposure to Chloroprene

	Total Cohort		HES		LES		CO		MM		OHE	
Age	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
<20	35	2.2	7	0.8	28	3.4	4	0.9	3	0.8	0	0.0
20-24	410	26.0	196	23.0	208	25.3	129	28.2	39	10.5	48	30.4
25-29	456	29.0	236	27.8	224	27.2	160	35.0	68	18.3	28	17.7
30-34	332	21.0	172	20.2	169	20.5	87	19.0	87	23.4	26	16.5
35-39	185	11.7	105	12.3	104	12.6	32	7.0	83	22.3	21	13.3
40-44	109	6.9	74	8.7	62	7.5	16	3.5	55	14.8	23	14.6
45-49	45	2.9	41	4.8	28	3.4	15	3.3	28	7.5	8	5.1
50-54	2	0.1	14	1.6	0	0.0	10	2.2	6	1.6	3	1.9
55-59	1	0.1	6	0.7	0	0.0	3	0.7	3	0.8	1	0.6
60-64	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0
Total	1575	100.0	851	100.0	823	100.0	457	100.0	372	100.0	158	100.0
Mean		29.4		30.8		29.5		29.0		34.2		31.4
95% confidence limits		29.0, 29.7		30.3, 31.4		29.1, 30.0		28.3, 29.7		33.4, 34.9		30.0, 32.7
Median		28		29		28		27		34		30

HES = "High Exposure" Subcohort
LES = "Low Exposure" Subcohort
CO = Chemical Operators
MM = Maintenance Mechanics
OHE = Other High Exposure Occupations

Table 5

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
Total Cohort, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All causes		193	244.9	79	(68, 91)
All malignant neoplasms	140-205	51	47.7	107	(80, 141)
MN of buccal cavity and pharynx	140-148	1	1.7		
MN of digestive system	150-159	19	13.1	145	(87, 227)
MN of esophagus	150	1	1.1		
MN of stomach	151	3	2.4	125	(26, 365)
MN of intestine except rectum	152,153	5	4.0	125	(41, 292)
MN of rectum	154	2	1.5		
MN of biliary passages and liver	155	4	0.7	571	(156,1463)
MN of pancreas	157	4	2.7	148	(40, 379)
MN of respiratory system	160-164	19	17.0	112	(67, 175)
MN of larynx	161	1	0.8		
MN of trachea, bronchus, and lung	162,163	17	16.0	106	(62, 170)
MN of other parts of respiratory system	160,164	1	0.2		

*The SMR is calculated only if the observed number of deaths is two or more.

Table 5
(continued)

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
MN of male genital system	177-179	2	2.2		
MN of prostate	177	2	1.8		
MN of urinary system	180-181	1	2.5		
MN of bladder and other urinary organs	181	1	1.2		
MN of other and unspecified sites	165, 190-199	2	6.2		
MN of lymphatic/ hematopoietic system	200-205	7	5.0	140	(56, 288)
Hodgkin's disease	201	2	0.8		
Leukemia and aleukemia	204	4	1.9	211	(57, 539)
Other neoplasms of lymphatic/ hematopoietic system	202,203,205	1	0.7		
Vascular lesions affecting central nervous system	330-334	18	13.3	135	(80, 214)
Diseases of the circulatory system	400-468	80	109.0	73	(58, 91)
Selected diseases of the digestive system	540,541,543, 560-570,581	6	11.3	53	(19, 116)
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	3	2.5	120	(25, 351)
Unknown causes	780-793,795	3	3.0	100	(21, 293)
Accidents	E800-962	15	19.2	78	(44, 129)
Other Causes		17	38.6	44	(26, 71)

*The SMR is calculated only if the observed number of deaths is two or more.

Table 6

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
"High Exposure" Subcohort, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All causes		91	120.8	75	(61, 92)
All malignant neoplasms	140-205	25	23.4	107	(69, 158)
MN of buccal cavity and pharynx	140-148	1	0.8		
MN of digestive system	150-159	8	6.4	125	(54, 246)
MN of esophagus	150	1	0.5		
MN of stomach	151	0	1.2		
MN of intestine except rectum	152,153	1	1.9		
MN of rectum	154	1	0.7		
MN of biliary passages and liver	155	3	0.4	750	(155,2192)
MN of pancreas	157	2	1.3		
MN of respiratory system	160-164	10	8.3	120	(58, 222)
MN of larynx	161	0	0.4		
MN of trachea, bronchus, and lung	162,163	10	7.8	128	(61, 236)
MN of other parts of respiratory system	160,164	0	0.1		

*The SMR is calculated only if the observed number of deaths is two or more.

Table 6
(continued)

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
MN of male genital system	177-179	1	1.0		
MN of prostate	177	1	0.9		
MN of urinary system	180-181	0	1.1		
MN of bladder and other urinary organs	181	0	0.6		
MN of other and unspecified sites	165, 190-199	1	3.1		
MN of lymphatic/ hematopoietic system	200-205	4	2.5	160	(44, 410)
Hodgkin's disease	201	2	0.4		
Leukemia and aleukemia	204	2	1.0		
Other neoplasms of lymphatic/ hematopoietic system	202,203,205	0	0.3		
Vascular lesions affecting central nervous system	330-334	3	6.4	47	(10, 137)
Diseases of the circulatory system	400-468	40	53.4	75	(54, 102)
Selected diseases of the digestive system	540,541,543, 560-570,581	3	5.7	53	(11, 154)
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	3	1.2	250	(52, 731)
Unknown causes	780-793,795	1	1.5		
Accidents	E800-962	7	9.8	71	(29, 147)
Other Causes		9	19.2	47	(21, 89)

*The SMR is calculated only if the observed number of deaths is two or more.

Table 7

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
"Low Exposure" Subcohort, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All causes		102	124.0	82	(67, 100)
All malignant neoplasms	140-205	26	24.3	107	(70, 157)
MN of buccal cavity and pharynx	140-148	0	0.9		
MN of digestive system	150-159	11	6.7	164	(82, 294)
MN of esophagus	150	0	0.6		
MN of stomach	151	3	1.2	250	(52, 731)
MN of intestine except rectum	152,153	4	2.0	200	(54, 512)
MN of rectum	154	1	0.8		
MN of biliary passages and liver	155	1	0.4		
MN of pancreas	157	2	1.4		
MN of respiratory system	160-164	9	8.6	105	(48, 199)
MN of larynx	161	1	0.4		
MN of trachea, bronchus, and lung	162,163	7	8.1	86	(35, 178)
MN of other parts of respiratory system	160,164	1	0.1		

*The SMR is calculated only if the observed number of deaths is two or more.

Table 7
(continued)

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
MN of male genital system	177-179	1	1.2		
MN of prostate	177	1	1.0		
MN of urinary system	180-181	1	1.3		
MN of bladder and other urinary organs	181	1	0.6		
MN of other and unspecified sites	165, 190-199	1	3.1		
MN of lymphatic/ hematopoietic system	200-205	3	2.5	120	(25, 351)
Hodgkin's disease	201	0	0.4		
Leukemia and aleukemia	204	2	1.0		
Other neoplasms of lymphatic/ hematopoietic system	202,203,205	1	0.4		
Vascular lesions affecting central nervous system	330-334	15	6.9	217	(122, 359)
Diseases of the circulatory system	400-468	40	55.7	72	(51, 98)
Selected diseases of the digestive system	540,541,543, 560-570,581	3	5.6	54	(11, 157)
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	0	1.3		
Unknown causes	780-793,795	2	1.5		
Accidents	E800-962	8	9.3	86	(37, 170)
Other Causes		8	19.3	41	(18, 82)

*The SMR is calculated only if the observed number of deaths is two or more.

Table 8

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
Chemical Operators, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All Causes		31	44.1	70	(48, 100)
All malignant neoplasms	140-205	8	8.2	98	(42, 192)
MN of buccal cavity and pharynx	140-148	1	0.3		
MN of digestive system	150-159	2	2.1		
MN of respiratory system	160-164	3	2.9	103	(21, 302)
MN of male genital system	177-179	0	0.3		
MN of urinary system	180-181	0	0.4		
MN of other and unspecified sites	156B,165, 190-199	0	1.2		
MN of lymphatic/ hematopoietic system	200-205	2	1.0		
Vascular lesions affecting central nervous system	330-334	1	1.8		
Diseases of the circulatory system	400-468	12	18.0	67	(34, 116)
Selected diseases of the digestive system	540,541,543, 560-570,581	1	2.4		
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	2	0.4		
Unknown causes	780-793,795	0	0.6		
Accidents	E800-962	3	5.0	60	(12, 175)
Other causes		4	7.6	53	(14, 135)

*The SMR is calculated only if the observed number of deaths is two or more.

Table 9

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
Maintenance Mechanics, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All causes		45	64.4	70	(51, 94)
All malignant neoplasms	140-205	12	12.7	94	(49, 165)
MN of buccal cavity and pharynx	140-148	0	0.5		
MN of digestive system	150-159	5	3.6	139	(45, 324)
MN of biliary passages and liver	155	3	0.2	1500	(309,4383)
MN of respiratory system	160-164	4	4.5	89	(24, 228)
MN of male genital system	177-179	1	0.6		
MN of urinary system	180-181	0	0.7		
MN of other and unspecified sites	156B,165, 190-199	1	1.6		
MN of lymphatic/ hematopoietic system	200-205	1	1.3		
Vascular lesions affecting central nervous system	330-334	1	3.8		
Diseases of the circulatory system	400-468	22	29.5	75	(47, 113)
Selected diseases of the digestive system	540,541,543, 560-570,581	2	2.9		
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	1	0.6		
Unknown causes	780-793,795	0	0.8		
Accidents	E800-962	2	4.3		
Other causes		5	9.8	51	(17, 119)

*The SMR is calculated only if the observed number of deaths is two or more.

Table 10

Chloroprene Mortality Study
Observed and Expected Numbers of Deaths and
Standardized Mortality Ratios for Selected Causes.
Other High Exposure Occupations, 1957-1974

Cause of Death	ICD Code (7th Rev.)	OBS	EXP	SMR*	95% Confidence Limits
All causes		16	19.8	81	(46, 131)
All malignant neoplasms	140-205	5	3.9	128	(42, 299)
MN of buccal cavity and pharynx	140-148	0	0.1		
MN of digestive system	150-159	1	1.1		
MN of respiratory system	160-164	3	1.4	214	(44, 626)
MN of male genital system	177-179	0	0.2		
MN of urinary system	180-181	0	0.2		
MN of other and unspecified sites	156B,165, 190-199	0	0.5		
MN of lymphatic/ hematopoietic system	200-205	1	0.4		
Vascular lesions affecting central nervous system	330-334	1	1.1		
Diseases of the circulatory system	400-468	7	9.0	78	(31, 160)
Selected diseases of the digestive system	540,541,543, 560-570,581	0	0.9		
Selected diseases of the genito-urinary system	590-600,602, 604,610-637	0	0.2		
Unknown causes	780-793,795	1	0.2		
Accidents	E800-962	2	1.4		
Other causes		0	3.1		

*The SMR is calculated only if the observed number of deaths is two or more.

Table 11

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
Total Cohort, 1957-1974

		< 10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	1	2.0	13	16.9	37	28.8	3.20
Buccal cavity and pharynx	140-148	0	0.1	0	0.6	1	1.0	0.60
Digestive system	150-159	0	0.5	5	4.6	14	8.0	1.59
Respiratory system	160-164	1	0.4	5	5.7	13	10.8	0.01
Male genital system	177-179	0	0.1	0	0.6	2	1.6	0.77
Urinary system	180-181	0	0.1	0	0.8	1	1.6	0.50
Other and unspecified sites	165, 190-199	0	0.4	0	2.5	2	3.3	1.49
Lymphatic/ hematopoietic system	200-205	0	0.4	3	2.0	4	2.6	0.29

*$p < .05$ if $X^2 > 3.84$

Table 12

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
"High Exposure" Subcohort, 1957-1974

		<10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	3	2.0	6	8.9	16	12.6	0.28
Buccal cavity and pharynx	140-148	0	0.1	0	0.3	1	0.4	0.80
Digestive system	150-159	1	0.5	2	2.4	5	3.5	0.01
Respiratory system	160-164	1	0.6	3	3.0	6	4.7	0.0009
Male genital system	177-179	0	0.1	0	0.3	1	0.7	0.48
Urinary system	180-181	0	0.1	0	0.4	0	0.7	0.00
Other and unspecified sites	165, 190-199	0	0.3	0	1.3	1	1.5	0.87
Lymphatic/ hematopoietic system	200-205	1	0.3	1	1.1	2	1.1	0.04

*$p < .05$ if $X^2 > 3.84$

Table 13

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
"Low Exposure" Subcohort, 1957-1974

		< 10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	0	1.0	7	8.5	19	14.9	2.06
Buccal cavity and pharynx	140-148	0	0.0	0	0.3	0	0.5	0.00
Digestive system	150-159	0	0.2	3	2.3	8	4.1	0.67
Respiratory system	160-164	0	0.2	3	2.8	6	5.6	0.04
Male genital system	177-179	0	0.0	0	0.3	1	0.8	0.37
Urinary system	180-181	0	0.0	0	0.4	1	0.8	0.50
Other and unspecified sites	165, 190-199	0	0.2	0	1.2	1	1.7	0.70
Lymphatic/ hematopoietic system	200-205	0	0.2	1	1.0	2	1.3	0.37

*$p < .05$ if $X^2 > 3.84$

Table 14

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
Chemical Operators, 1957-1974

		<10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	1	0.9	3	3.0	4	4.3	0.02
Buccal cavity and pharynx	140-148	0	0.0	0	0.1	1	0.2	0.50
Digestive system	150-159	0	0.2	1	0.7	1	1.1	0.01
Respiratory system	160-164	0	0.2	1	1.0	2	1.7	0.17
Male genital system	177-179	0	0.0	0	0.0	0	0.1	0.00
Urinary system	180-181	0	0.0	0	0.1	0	0.2	0.00
Other and unspecified sites	165, 190-199	0	0.2	0	0.5	0	0.6	0.00
Lymphatic/ hematopoietic system	200-205	1	0.2	1	0.4	0	0.4	1.75

*$p < .05$ if $X^2 > 3.84$

Table 15

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
Maintenance Mechanics, 1957-1974

		< 10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	1	1.4	2	4.9	9	6.4	1.94
Buccal cavity and pharynx	140-148	0	0.1	0	0.2	0	0.2	0.00
Digestive system	150-159	0	0.4	1	1.4	4	1.8	1.83
Respiratory system	160-164	1	0.4	1	1.7	2	2.4	0.35
Male genital system	177-179	0	0.0	0	0.2	1	0.4	0.50
Urinary system	180-181	0	0.0	0	0.1	0	0.2	0.00
Other and unspecified sites	165, 190-199	0	0.2	0	0.7	1	0.7	1.01
Lymphatic/ hematopoietic system	200-205	0	0.2	0	0.5	1	0.6	0.92

*$p < .05$ if $X^2 > 3.84$

Table 16

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Latency
Other High Exposure Occupations, 1957-1974

		< 10 Years of Latency		10 to 20 Years of Latency		20+ Years of Latency		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	1	0.5	1	1.4	3	2.0	0.002
Buccal cavity and pharynx	140-148	0	0.0	0	0.1	0	0.1	0.00
Digestive system	150-159	1	0.1	0	0.4	0	0.6	0.00
Respiratory system	160-164	0	0.2	1	0.5	2	0.7	0.55
Male genital system	177-179	0	0.0	0	0.0	0	0.1	0.00
Urinary system	180-181	0	0.0	0	0.1	0	0.1	0.00
Other and unspecified sites	165, 190-199	0	0.1	0	0.2	0	0.2	0.00
Lymphatic/ hematopoietic system	200-205	0	0.1	0	0.2	1	0.2	1.14

*$p < .05$ if $X^2 > 3.84$

Table 17

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
Total Cohort, 1957-1974

		<10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	4	4.3	21	19.8	26	23.5	0.09
Buccal cavity and pharynx	140-148	0	0.1	0	0.7	1	0.9	0.76
Digestive system	150-159	1	1.1	8	5.6	10	6.3	0.25
Respiratory system	160-164	1	1.3	6	6.6	12	9.1	0.68
Male genital system	177-179	0	0.2	2	1.0	0	1.0	0.64
Urinary system	180-181	0	0.2	1	1.0	0	1.2	0.42
Other and unspecified sites	165, 190-199	0	0.7	1	2.7	1	2.8	0.11
Lymphatic/ hematopoietic system	200-205	2	0.7	3	2.2	2	2.1	1.13

*$p < .05$ if $X^2 > 3.84$

Table 18

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
"High Exposure" Subcohort, 1957-1974

		<10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	9	7.4	9	8.8	7	7.1	0.18
Buccal cavity and pharynx	140-148	0	0.3	0	0.3	1	0.3	1.50
Digestive system	150-159	4	2.0	4	2.5	0	1.9	3.08
Respiratory system	160-164	2	2.5	2	3.0	6	2.8	2.07
Male genital system	177-179	0	0.3	1	0.4	0	0.3	0.00
Urinary system	180-181	0	0.4	0	0.5	0	0.4	0.00
Other and unspecified sites	165, 190-199	1	1.1	0	1.2	0	0.8	1.35
Lymphatic/ hematopoietic system	200-205	2	0.9	2	0.9	0	0.6	0.92

*$p < .05$ if $X^2 > 3.84$

Table 19

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
"Low Exposure" Subcohort, 1957-1974

		< 10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	2	2.4	11	10.1	13	11.8	0.07
Buccal cavity and pharynx	140-148	0	0.1	0	0.4	0	0.4	0.00
Digestive system	150-159	1	0.6	3	2.9	7	3.2	0.65
Respiratory system	160-164	0	0.7	4	3.3	5	4.5	0.25
Male genital system	177-179	0	0.1	1	0.5	0	0.5	0.32
Urinary system	180-181	0	0.1	1	0.5	0	0.6	0.42
Other and unspecified sites	165, 190-199	0	0.4	1	1.3	0	1.4	0.21
Lymphatic/ hematopoietic system	200-205	1	0.4	1	1.1	1	1.0	0.34

*$p < .05$ if $X^2 > 3.84$

Table 20

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
Chemical Operators, 1957-1974

		< 10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	3	2.9	2	2.4	3	2.8	0.00
Buccal cavity and pharynx	140-148	0	0.1	0	0.1	1	0.1	1.50
Digestive system	150-159	2	0.7	0	0.6	0	0.7	2.85
Respiratory system	160-164	0	1.0	1	0.8	2	1.1	1.65
Male genital system	177-179	0	0.1	0	0.1	0	0.1	0.00
Urinary system	180-181	0	0.1	0	0.1	0	0.1	0.00
Other and unspecified sites	165, 190-199	0	0.5	0	0.4	0	0.4	0.00
Lymphatic/ hematopoietic system	200-205	1	0.4	1	0.3	0	0.3	0.46

*$p < .05$ if $X^2 > 3.84$

Table 21

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
Maintenance Mechanics, 1957-1974

		<10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	3	4.0	7	5.3	2	3.4	0.02
Buccal cavity and pharynx	140-148	0	0.1	0	0.2	0	0.1	0.00
Digestive system	150-159	1	1.1	4	1.5	0	0.9	0.17
Respiratory system	160-164	1	1.4	1	1.8	2	1.3	0.49
Male genital system	177-179	0	0.2	1	0.3	0	0.2	0.00
Urinary system	180-181	0	0.2	0	0.3	0	0.2	0.00
Other and unspecified sites	165, 190-199	1	0.6	0	0.6	0	0.4	1.25
Lymphatic/ hematopoietic system	200-205	0	0.5	1	0.5	0	0.3	0.04

*$p < .05$ if $X^2 > 3.84$

Table 22

Chloroprene Mortality Study
Observed and Expected Numbers of Cancer Deaths
by Major Organ System and by Duration of Exposure
Other High Exposure Occupations, 1957-1974

		<10 Years of Exposure		10 to 20 Years of Exposure		20+ Years of Exposure		
Primary Site	ICD Code (7th Rev.)	OBS	EXP	OBS	EXP	OBS	EXP	X^{2*}
All malignant neoplasms	140-205	3	2.0	0	1.2	2	0.7	0.15
Buccal cavity and pharynx	140-148	0	0.1	0	0.0	0	0.0	0.00
Digestive system	150-159	1	0.5	0	0.3	0	0.2	0.80
Respiratory system	160-164	1	0.7	0	0.4	2	0.3	1.81
Male genital system	177-179	0	0.1	0	0.1	0	0.0	0.00
Urinary system	180-181	0	0.1	0	0.1	0	0.0	0.00
Other and unspecified sites	165, 190-199	0	0.3	0	0.1	0	0.1	0.00
Lymphatic/ hematopoietic system	200-205	1	0.2	0	0.1	0	0.1	0.81

*$p < .05$ if $X^2 > 3.84$

Appendix A

High Exposure Job Category	Code	Occupation
Chemical Operators:	07	Chemical Operator (not defined)
	09	Chemical Operator (monomer)
	10	Chemical Operator (polymer)
	57	C.D. Chemical Operator
Maintenance Mechanics:	28	Maintenance Mechanic
Other High Exposure Occupations:	11	Clean-up Operator
	21	Helper
	58	C.D. Helper
	60	Poly Unit Mechanic
	75	Process Mechanic
	87	Foreman (MVA; monomer)
	89	Foreman (polymer)
	90	Foreman (C.D. monomer)
	A8	Maintenance Mechanic Helper
	B2	Polymer Mill Operator