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Mortality Among Workers at a Plastics Manufacturing and Research and Development Facility: 1946–1988

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Mortality through 1988 was studied for 5,932 male employees who worked between January 1, 1946 and December 31, 1967 at a New Jersey plastics manufacturing and research and development facility. The cohort was followed for an average of 32 years and included 1,859 deaths. Potential exposures included asbestos, formaldehyde, and polyvinyl chloride (PVC). Mortality rates for the cohort were compared to both U.S. and state mortality rates, and analyses were also performed by lagging duration of employment. Based on U.S. rates, mortality among hourly males (n = 3,853) from all cancers was similar to expected [standardized mortality ratio (SMR), 102; 95% confidence interval (CI), 92–114]. Excess mortality among hourly workers was seen for pancreatic cancer (SMR, 146; 95% CI, 95–216) and "malignancies of other parts of the respiratory system" (SMR, 373; 95% CI, 121–870). The latter excess was due entirely to five deaths from pleural mesothelioma. There were no deaths identified due to nasal cavity or nasopharyngeal cancers, or angiosarcoma of the liver. Mortality from leukemia among research and development workers (n = 1,421) was significantly elevated (SMR, 265; 95% CI, 115–524) and related to assignment to process development. This study verifies the excess of pancreatic cancer among workers at the facility seen in earlier studies and observes excesses of mesothelioma due to asbestos exposure and leukemia in process development workers.

Key words: asbestos, laboratory personnel, leukemia, mesothelioma, pancreatic neoplasms, plastics, polyvinyl chloride

INTRODUCTION

The Bound Brook, New Jersey plastics manufacturing plant began operation in 1931 as a manufacturer of phenol-formaldehyde resins. These thermosetting phenolic resins provided for the mass production of molding compounds used in insulation, electrical, automotive, and communication applications. In about 1939, a major research and development facility was added to the site. Research conducted at this

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facility led to the development and production of vinyl polymers and copolymers, phenoxy resins, and high- and low-density polyethylene compounds. Raw materials used in the manufacturing process included asbestos (usually chrysotile), which was used as a filler in the production of molding materials. Other materials used or produced at the plant included carbon black, epichlorohydrin, formaldehyde, polyvinyl chloride (PVC), acrylonitrile, styrene, and numerous chemical additives, such as plasticizers, emulsifiers, and antioxidants.

In 1977, university researchers enumerated workers at the facility to study cancer mortality. The cohort consisted of male employees who had worked between 1946 and 1967. The study was motivated by an interindustry report on mortality among PVC fabricators and an unrelated observation by the plant physician suggesting an excess of pancreatic cancer among workers. The findings through 1977 were essentially null regarding pancreatic cancer and other cancers [University of Pennsylvania School of Medicine, Department of Research Medicine, "Cancer Mortality Within the Chemical Industry: A Report for Union Carbide Corporation," March 1981]. The study, however, received much criticism from peer reviewers. Questions were raised regarding the criteria for inclusion in the study population, which prompted an internal audit to validate the completeness of the cohort [Teta MJ, "University of Pennsylvania Bound Brook Epidemiology Study: Cohort Completeness Audit." Internal UCC report, February 27, 1987]. After verifying that the cohort was reasonably complete and rectifying the other substantive criticisms, a decision was made to update and reassess mortality for the workers. A preliminary report by company epidemiologists with follow-up through 1983 found an excess of pancreatic cancer among hourly workers [SMR, 162; 95% confidence interval (CI), 100–247], with a nearly twofold, statistically significant excess among workers employed for 10 years or more (SMR, 188; 95% CI, 108–306) [Teta MJ, "UCC Bound Brook Cohort Mortality Study: Preliminary Report," Internal UCC Draft Report, March 18, 1988]. These results prompted a nested case-control study of pancreatic cancer among workers at the Bound Brook facility, which is reported elsewhere [Selenskas et al., 1995]. In conjunction with the nested case-control study of pancreatic cancer, mortality for the entire cohort was updated through 1988. This paper presents the results from the mortality reanalysis.

MATERIALS AND METHODS

The study population consisted of 5,945 male employees who worked for at least 7 months between January 1, 1946 and December 31, 1967. The 7 month minimum length of employment criteria corresponded to an employee probation period and was imposed at the time the cohort was assembled in 1977. Mortality was assessed through December 31, 1988. Vital status was ascertained for the cohort using company records, files of the Social Security Administration, and the National Death Index of the National Center for Health Statistics. After exclusions for missing dates of hire, birth, or termination of employment, 5,932 workers remained for analysis. Death certificates were collected and coded for underlying cause of death by a trained nosologist according to the revision of the International Classification of Diseases (ICD) in effect at time of death.

The data were analyzed using standard person-years at risk analysis [Ott et al., 1985]. Age- and calendar year-specific mortality rates for the U.S. (1940–1989) and

New Jersey (1950–1989) white male populations were used to obtain an expected number of cause-specific deaths. Since New Jersey mortality rates were not available before 1950, 131 study subjects whose date last observed was prior to January 1, 1950 were excluded from the state comparisons.

Person-years at risk began accumulating as of January 1, 1946 or the date of entry into the cohort (7 months after date of hire), whichever was more recent. Person-years at risk were calculated until date last observed, that is, date of death, date lost to follow-up, or December 31, 1988 for those alive at the close of the study. Exact 95% confidence intervals for the SMRs were calculated under the assumption that the observed number of deaths follow a Poisson distribution [Marsh and Preininger, 1980]. Separate analyses were conducted for hourly and salaried employees stratified by length of employment, date of hire, and time since hire.

Duration of employment, an indirect measure of cumulative exposure, was lagged in a time-dependent manner by 10- and 15-year intervals to account for latency. Study subjects were assigned to duration of employment categories attained by the individual 10 and 15 years, respectively, prior to the date last observed [Checkoway et al., 1990]. This method of lagging exposure assumes that recent exposures are not causally related to the disease while utilizing all person-years in the cohort.

Limited analyses by assignment to major work department were conducted because work history data prior to 1946 and after 1967 were not collected when the cohort was first investigated. As a result of the truncated department assignment data, department-specific duration of assignment analyses are not presented.

In addition, death certificates for members of the study population were manually searched to identify additional cases of asbestosis and mesothelioma possibly listed as contributory causes of death and cases of mesothelioma listed as the underlying cause of death. (Prior to the Ninth Revision of the ICD, there was no specific code designated solely for mesothelioma.) Since there was potential exposure to vinyl chloride, death certificates for liver cancer decedents were similarly searched to determine whether any deaths were recorded as angiosarcoma of the liver.

RESULTS

Vital status was determined for 94% of the cohort (Table I). Through December 31, 1988, 1,859 members (31%) of the cohort were known to be deceased, and nearly 92% of these deaths occurred among study subjects hired before 1957. Death certificates were obtained for approximately 98% of the decedents. Of the 365 members considered lost to follow-up, 259 (71%) worked less than 5 years. The average time since hire to date last observed for study subjects was 31.8 years, and the average length of employment was 15.4 years.

Based on U.S. comparisons, the 3,853 male hourly workers (Table II) demonstrated a deficit in mortality from all causes (SMR, 95; 95% CI, 90–100). Mortality for total cancers (SMR, 102; 95% CI, 92–114) and for heart disease (SMR, 102; 95% CI, 94–110) for the hourly subcohort did not appear to differ substantially from U.S. rates. When examined by duration of employment, mortality from total cancers for the hourly group was significantly elevated for subjects who had worked at the plant between 10 and 19 years (SMR, 136; 95% CI, 108–169). For those employed at least

TABLE I. Vital Status as of December 31, 1988 of the Bound Brook, New Jersey Cohort (n = 5,932) by Time of Hire and Length of Employment

Year of first hire and duration of employment	Total	Vital status		
		Alive (n=3708)	Dead (n=1859)	Unknown (n=365)
First hired before 1946				
Total	1,437	565	847	25
<5 years	168	63	88	17
5–9 years	174	69	101	4
10–19 years	248	59	188	1
≥20 years	847	374	470	3
Hired 1946–1956				
Total	2,841	1,787	854	200
<5 years	1,146	643	359	144
5–9 years	236	140	71	25
10–19 years	393	186	180	27
≥20 years	1,066	818	244	4
Hired 1957–1967				
Total	1,654	1,356	158	140
<5 years	817	652	61	98
5–9 years	266	204	32	30
10–19 years	213	155	48	10
≥20 years	358	339	17	2

20 years, cancer mortality was slightly lower than expected when compared to U.S. rates (SMR, 89; 95% CI, 74–105).

The hourly group exhibited higher pancreatic cancer mortality than the U.S. (SMR, 146; 95% CI, 95–216) and New Jersey (SMR, 131; 95% CI, 84–195) groups. There was no clear duration-response trend, although the excesses were greatest in the 10–19 year length of employment group and those who worked 20 years or more (Table III). When a 10-year lag interval was applied to duration of employment, the pancreatic cancer SMR for workers with 10–19 years employment was 211 (95% CI, 84–434) and increased to 238 (95% CI, 103–469) when a 15-year lag interval was applied. Mortality from cancer of the biliary passages, liver, and gallbladder showed a nonsignificant excess, with seven observed cases compared to 5.2 expected. A review of death certificates where cancer of the liver was recorded as the cause of death failed to identify any deaths due to angiosarcoma of the liver.

Mortality from cancer of the bronchus, trachea, and lung was slightly higher than U.S. rates (SMR, 110; 95% CI, 92–131) and New Jersey rates (SMR, 108; 95% CI, 90–129) for hourly workers. Although there was no apparent positive trend between time since hire and mortality, there was increasing mortality between 10 and 19 years since hire. The risk by duration of employment peaked among subjects with a 10–19 year length of employment (SMR, 138; 95% CI, 90–202). The mortality trends persisted when exposure was lagged by 10 and 15 years (Table IV). There were significantly more lung cancer deaths than expected among workers employed 10–19 years when a 10 year lag interval was applied (SMR, 162; 95% CI, 111–229) and when a 15 year lag interval was applied (SMR, 173; 95% CI, 121–241). Workers employed 20 years or more, however, experienced significantly fewer deaths than

TABLE II. Observed and Expected Deaths, 1946–1988, by Selected Causes for 3,853 Male Hourly Employees of the Round Brook, New Jersey Plant

Cause of death category	Observed/expected[c] deaths	SMR	95% CI
All causes	1,401/1,477.30	95[b]	(90–100)
Malignant neoplasms, total	334/327.08	102	(92–114)
Digestive organs and peritoneum	96/87.25	110	(89–134)
Intestine, except rectum	30/30.16	99	(67–142)
Rectum	13/8.55	152	(81–260)
Biliary passages, liver, and gallbladder	7/5.22	134	(54–276)
Pancreas	25/17.08	146	(95–216)
Respiratory system	132/118.67	111	(93–132)
Larynx	3/4.69	64	(13–187)
Bronchus, trachea, and lung	124/112.65	110	(92–131)
Other parts of respiratory system	5/1.34	373[a]	(121–870)
Kidney	7/8.14	86	(35–177)
Bladder and other urinary organs	7/8.96	78	(31–161)
Skin	8/6.12	131	(56–258)
Brain and other parts of nervous system	6/9.54	63	(23–137)
Lymphatic and hematopoietic tissue	28/30.08	93	(62–135)
Lymphosarcoma and reticulosarcoma	3/5.48	55	(11–160)
Leukemia and aleukemia	12/12.31	98	(50–170)
Other lymphatic and hematopoietic	10/9.30	108	(52–198)
Benign neoplasms	5/4.52	111	(36–258)
Cerebrovascular disease	69/86.57	80	(62–101)
Heart disease	616/604.84	102	(94–110)
Diseases of respiratory system	74/96.20	77[a]	(60–97)
Other	280/358.10	78[b]	(69–88)
Unable to locate death certificates	31		

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] Expected deaths based on U.S. white male mortality rates, 1940–1989.

TABLE III. Observed and Expected Deaths From Malignancies of the Pancreas Among Hourly Males, According to Duration of Employment, Lagged 10 and 15 Years

	Lag interval (years)					
	0		10		15	
Duration of employment	Obs./exp.	SMR (95% CI)	Obs./exp.	SMR (95% CI)	Obs./exp.	SMR (95% CI)
<5 years	6/4.37	137 (50–299)	7/4.44	158 (63–323)	10/4.61	217[a] (104–399)
5–9 years	2/1.70	118 (13–425)	4/1.75	229 (61–308)	3/1.93	155 (31–454)
10–19 years	6/3.23	186 (68–404)	7/3.32	211 (84–434)	8/3.36	238[a] (103–469)
≥20 years	11/7.79	141 (70–253)	7/7.58	92 (37–190)	4/7.18	56 (15–143)

[a] $p < 0.05$.
Obs., observed; exp., expected.

TABLE IV. Observed and Expected Deaths From Malignancies of the Trachea, Lung, and Bronchus Among Hourly Males at the Bound Brook, New Jersey Plant, According to Duration of Employment, Lagged 10 and 15 Years

	Lag interval (years)					
	0		10		15	
Duration of employment	Obs./exp	SMR (95% CI)	Obs./exp.	SMR (95% CI)	Obs./exp.	SMR (95% CI)
<5 years	31/29.41	105 (72–150)	36/29.67	121 (85–168)	44/30.52	144[a] (105–194)
5–9 years	13/10.54	123 (66–211)	18/10.81	167 (99–263)	19/12.09	157 (95–245)
10–19 years	26/18.87	138 (90–202)	32/19.74	162[a] (111–229)	35/20.18	173[b] (121–241)
≥20 years	54/53.82	100 (75–131)	38/52.41	73[a] (51–100)	26/49.83	52[b] (34–76)

[a] $p < 0.05$.
[b] $p < 0.01$.
Obs., observed; exp., expected.

expected when exposures were lagged for both 10 years (SMR, 73; 95% CI, 51–100) and 15 years (SMR, 52; 95% CI, 34–76).

Because the plant manufactured and used formaldehyde, the data were examined for deaths from cancer of the nasopharynx or nasal cavities. There were no deaths reported from either cause. There were only 111 men, however, with assignments involving formaldehyde.

There was a statistically significant excess of deaths from malignancies of other parts of the respiratory system with five observed and 1.3 expected (SMR, 373; 95% CI, 121–870) in the hourly group. Pleural mesotheliomas accounted for the five deaths, all of which appeared among those with at least 20 years since date of hire. There were three deaths (0.6 expected) due to this cause among those employed 20 years or more. A review of death certificates for the entire cohort revealed an additional four deaths from pleural mesothelioma as contributory causes of death during the observation period (a fifth death occurred after the close of the study) (Table V). No deaths due to peritoneal mesothelioma were identified. Of the nine deaths from pleural mesothelioma that occurred during the study period, the average latency was 33.4 years and the average length of employment was 19.3 years. Of the total 10 deaths from pleural mesothelioma, four of the decedents had worked at some time during their employment in resins and varnish processing, three had worked in vinyl and polyethylene processing, and two in resins pulverizing. One decedent, whose department work history was not known, had worked for less than 1 year. Additionally, there were four deaths attributed to asbestosis. Two of these subjects worked 3 years or less and had previously been employed at a nearby asbestos processing plant.

Among hourly workers, there were also eight observed deaths (6.1 expected) from malignancies of the skin. However, among workers who were hired prior to 1946 and who had 20 or more years since first exposure, there were four observed deaths from malignancies of the skin compared to 1.2 expected (SMR, 331; 95% CI, 90–846).

The salary subcohort ($n = 2,079$) exhibited decreased mortality rates of 30%

TABLE V. Characteristics of Decedents From Asbestos-Related Diseases Among 5,932 Workers in the Bound Brook, New Jersey Cohort

	Year of hire	Age at hire	Duration (yrs.)	Time since hire (yrs.)	Age at death	Department assignments: Longest duration	Department assignments: Other/previous work history
Pleural mesothelioma							
1.	1935	19	35	41	60	Resins and varnish 31 yrs.	Molding materials
2.	1939	18	7	47	65	Unknown-'39–'46	Vinyls and polyethylene
3.	1946	25	8	29	55	Resins and varnish	Unknown-'51–'54
4.	1946	35	24	37	73	Resins and varnish	
5.	1947	35	26	28	63	Polystyrene 24 yrs.	Resins and varnish '47–'49
6.	1959	24	<1	21	45	Unknown	
7.*	1950	19	38	38	57	Vinyls and polyethylene '50–'67	Phenol
8.	1950	23	32	36	59	Molding materials 22 yrs.	Vinyls and polyethylene
9.	1951	31	12	33	64	Plant service	
10.	1952	37	26	26	64	R&D	
Asbestosis							
1.	1943	35	3	45	80	Plant service	Asbestos company
2.	1947	45	1	41	86	Resins and varnish	Asbestos company
3.	1948	39	8	35	74	Unknown '51–'55	Polystyrene '48–'50
4.	1952	34	25	35	69	Maintenance	

*Deceased after close of study.

when compared to the U.S. white male population (Table VI). The salary workers experienced decreased mortality of 27% for all heart disease and decreased mortality of 12% for all cancers. Salary workers experienced approximately one-half the mortality from respiratory cancer as the U.S. white male population (SMR, 51; 95% CI, 34–75) and New Jersey white male population (SMR, 50; 95% CI, 33–73).

Among salary workers, malignancies of lymphatic and hematopoietic tissue were elevated when compared to U.S. rates (SMR, 169; 95% CI, 107–253), largely attributable to elevated rates of death from leukemia (SMR, 198; 95% CI, 99–354) and multiple myeloma (five observed; 1.91 expected; SMR, 262; 95% CI, 85–611) in the category of other lymphatic and hematopoietic cancers. Although an attempt was made to lag duration of employment by 10 and 15 years to account for latency with the leukemia deaths, small numbers of expected deaths across all strata of duration of employment resulted in unstable estimates of effect. However, workers with less than 5 years duration of employment demonstrated the largest excesses after applying both lag intervals. Plant work history information was obtained for the 11 leukemia deaths and the five multiple myeloma deaths. Three of the five multiple myeloma decedents had worked in plant services and 8 of the 11 leukemia decedents

TABLE VI. Observed and Expected Deaths, 1946–1988, by Selected Causes for 2,079 Male Salary Employees of the Bound Brook, New Jersey Plant

Cause of death category	Observed/expected* deaths	SMR**	95% CI
All causes	458/657.40	70[b]	(63–76)
Malignant neoplasms, total	128/145.40	88	(73–105)
Digestive organs and peritoneum	43/38.29	112	(81–151)
Intestine, except rectum	20/13.39	149	(91–231)
Rectum	4/3.68	109	(30–278)
Biliary passages, liver and gallbladder	1/2.30	43	(1–242)
Pancreas	6/7.52	80	(29–174)
Respiratory system	27/52.64	51[b]	(34–75)
Kidney	2/3.64	55	(7–199)
Bladder and other urinary organs	3/3.93	76	(16–223)
Skin	3/2.93	102	(21–299)
Brain and other parts of nervous system	3/4.34	69	(14–202)
Lymphatic and hematopoietic tissue	23/13.63	169[a]	(107–253)
Lymphosarcoma and reticulosarcoma	3/2.39	126	(26–367)
Leukemia and aleukemia	11/5.56	198	(99–354)
Other lymphatic and hematopoietic	8/4.30	186	(80–367)
Benign neoplasms	1/1.99	—	(1–280)
Cerebrovascular disease	25/38.20	65[a]	(42–97)
Heart disease	192/264.70	73[b]	(63–84)
Diseases of respiratory system	20/42.61	47[b]	(29–73)
Other	85/164.54	52[b]	(41–64)
Unable to locate death certificate	12		

[a] $p < 0.05$.
[b] $p < 0.01$.
*Expected deaths based on U.S. white male mortality rates, 1940–1989.
**SMR not calculated when observed and expected numbers of death are both less than 2.

had worked in research and development (R&D) (Table VII). Since leukemia mortality appeared to be concentrated among R&D workers, an additional analysis was performed on all study subjects who were ever assigned to R&D, both hourly and salary, at the facility between 1946 and 1967 (n = 1,421). There were eight deaths from leukemia compared to 3.0 expected (SMR, 265; 95% CI, 115–524) and three deaths (1.1 expected) from multiple myeloma. All three decedents from multiple myeloma were hourly workers.

In general, SMRs for cancers for both the hourly group and the salary group looked more favorable when compared to New Jersey white males than to U.S. white males due to higher mortality rates from cancer in New Jersey. The patterns of excesses and deficits were not substantially altered, however.

DISCUSSION

This study examined mortality through 1988 for a cohort of male workers who were employed between 1946 and 1967 at a plastics manufacturing and research and development facility. Among hourly workers, excess mortality was observed for pancreatic cancer and "other malignancies of the respiratory system." There was only a weak elevation in lung cancer mortality, although there appeared to be a duration-response trend for those employed less than 20 years, which persisted when

TABLE VII. Characteristics of Decedents From Leukemia Among 2,079 Salary Workers in the Bound Brook, New Jersey Cohort

Year of hire	Age at hire	Duration (yrs)	Time since hire (yrs.)	Age at death	Dept. assignment longest duration	Type of leukemia*
1925	34	24	24	58	Unknown	Lymphocytic, n.o.s.
1931	16	39	40	56	R&D	Acute, n.o.s.
1947	27	3	36	63	R&D	Acute monocytic
1953	35	17	33	68	R&D	Chronic lymphocytic
1957	54	10	10	64	R&D	Acute blastic
1958	27	8	8	35	R&D	Chronic myelocytic
1958	33	24	24	57	R&D	Acute myelocytic
1958	43	17	17	60	R&D	Acute myelocytic
1963	38	22	23	61	Distribution	Chronic lymphocytic
1964	21	<1	15	36	R&D	Acute, n.o.s.
1964	36	1	22	58	Distribution	Lymphosarcoma cell leukemia

*As listed on death certificate.

duration of employment was lagged by 10 and 15 years, respectively. After 20 years or more length of employment, relative mortality from lung cancer decreased, possibly the result of a survivor effect or fewer smokers among long-term workers. The pancreatic cancer excess was investigated in a case-control study that examined specific work-related factors [Selenskas et al., 1995]. A sevenfold increased risk of pancreatic cancer among hourly workers who were assigned more than 16 years to vinyl processing was reported (based on five cases). No other work assignments appeared to be related to the pancreatic cancer excess.

The elevation in mortality from "other malignancies of the respiratory system" was entirely due to pleural mesothelioma. The period of time between onset of exposure and diagnosis of an asbestos-related disease typically exceeds 20 years [Fraumeni and Blot, 1982]. Selikoff et al. [1980] reported that the latency period for asbestosis and mesothelioma was 30–40 years from first exposure. This is consistent with the results of the present study, in which the average length of time since hire for the nine mesothelioma deaths that occurred during the study period was 33.4 years.

Mortality from mesothelioma is underestimated when the underlying cause of death is used to identify cases [Newhouse and Wagner, 1969]. In this study, the number of mesothelioma cases increased from five to nine when all causes of death were examined. Asbestos, which was processed to remove coarser fibers to provide for better dispersal as a filler, acted to increase the heat resistance of the molding compound and was used in the vinyls lab and the resin pulverizing department. An industrial hygiene report on dust concentrations in the resin pulverizing department from late 1968 documented dust levels between 8.7 and 20.1 million particles per cubic foot of air with numerous asbestos fibers noted. However, mortality from lung cancer among those who worked between 1946 and 1967 in the resin pulverizing department was similar to expected (20 observed, 19.4 expected). The use of asbestos may not have been limited to these departments because a case review indicated that four of the mesothelioma cases had been assigned to the resins and varnish department. The possibility that some of these cases were exposed to asbestos prior to

working at the Bound Brook facility cannot be ruled out because there was evidence that two of the four asbestosis cases were previously employed at a neighboring asbestos products manufacturing plant.

The results of this study were not consistent with the findings of a study of asbestos insulation workers in which misdiagnosed cases of peritoneal mesothelioma were reported as pancreatic cancer on death certificates [Selikoff and Seidman, 1981]. A National Institute for Occupational Safety and Health review concluded that the death certificate reports of pancreatic cancer among members of the Bound Brook cohort agreed with the available medical records [Selenskas et al., 1994]. In addition, a manual search through death certificates failed to reveal any deaths that were attributed to peritoneal mesothelioma.

Although formaldehyde was manufactured and used at the plant during most of the study period, there were no cancers of the nasal cavity or nasopharynx reported on death certificates as the underlying cause of death. Cancer of the nasal cavity or nasopharynx has been linked to exposure to formaldehyde [Hayes et al., 1986; Blair et al., 1990a; Olsen et al., 1984]. However, nasal cancer is a very rare disease, and the present study has small power to detect an excess risk. The results of the present study support the findings of other studies that reported elevated risks for lung cancer among workers producing formaldehyde resins and molding compounds [Blair et al., 1990b; Bertazzi et al., 1986]. Among the 57 men who had been assigned to hexamethyleneteramine production, there was an excess of lung cancer based on four cases (1.1 expected). Blair et al. [1990b] reported that workers assigned to hexamethyleneteramine had a lung cancer SMR of 2.0 after 20 years latency, which was significant for those assigned 10–19 years.

Among the R&D workers, the number of observed deaths (eight) from leukemia exceeded the expected deaths (three). Several studies have reported a significant excess of leukemia and lymphatic cancer among R&D personnel and scientists [Li et al., 1969; Olin and Ahlbom, 1980; Maher and Defonso, 1986; Arnetz et al., 1991]. Although the R&D category included analytic chemists, an examination of work history records suggested that the decedents were associated with process development in the two research pilot plants where chemical engineers, lab technicians, and pilot plant operators executed relatively small-scale product development. Laboratory notebooks were examined and interviews were conducted with veteran current and former workers, who were assigned to R&D in the late 1950s and early 1960s, to identify possible exposures or processes shared by the decedents. There did not appear to be obvious common projects or exposures, except in general terms, that is, numerous references to solvents such as benzene and toluene. Several of the men transferred from an older polymer process development facility that closed in the late 1950s.

This investigation also noted an excess of malignancies of the skin among hourly workers who were hired before 1946 and worked for at least 20 years, two of whom were maintenance workers. Several studies in recent years have reported an excess of malignancies of the skin among maintenance workers [Nelson et al., 1989; Teta et al., 1991].

Smoking information is not available for members of the cohort. It is not known if smoking patterns among study members differed substantially from those of the general population for most of the period of observation. Teta et al. [1990] reported that an examination of medical records from 1978 to 1987 for men under surveillance

at the Bound Brook facility, in accordance with the Occupational Safety and Health Administration asbestos standard, suggested similar smoking patterns as the general U.S. population. In addition, other cancers associated with tobacco smoke (pharynx, bladder, larynx, and esophagus) were not increased.

There was no evidence of a healthy worker effect in the present study when mortality from all cancers was examined. Because the minimum length of follow-up was 21 years and the average length of follow-up was 33 years, it also seems likely that any healthy worker effect that previously existed in the cohort was attenuated by a lengthy follow-up.

CONCLUSIONS

This study found that the excess of pancreatic cancer seen in previous studies on this group of workers employed in plastics manufacturing persists. A follow-up study has found a strong relationship between pancreatic cancer and long-term assignment to vinyl processing. Excesses of mesothelioma related to asbestos exposure and leukemia among R&D workers were also evident.

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