Mortality Among Employees of PVC Fabricators

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A cross-sectional mortality study of 4,341 deaths occurring among current and former employees of 17 PVC fabricators during 1964-1973 is presented. The objectives are: (1) to identify any angiosarcoma deaths among the employees of these fabricators, and (2) to examine the distribution of deaths by cause. No angiosarcoma deaths were found among the study group. Sex-race-cause-specific Proportionate Mortality Ratios (PMR's) were computed, using the corresponding U.S. mortality as the standard. Among white employees, there appears to be an excess in total cancer mortality, particularly that of the digestive system. Observed deaths were found to exceed the expected in cancers of the breast and urinary organs among white females. Deficit mortality was observed in cirrhosis of liver among both male and female white employees.

The January 1974 disclosure of three deaths from angiosarcoma of the liver in a single vinyl chloride polymerization plant and the attention focused on this new occupational disease are well known. A significant amount of information from animal experimentation and observation on humans engaged in the production of vinyl chloride followed.[1] However, there was no information regarding the possible adverse effects on employees engaged in polyvinyl chloride (PVC) fabrication, where potential exposures were thought to be low and to result from the release of unreacted monomer trapped in the resin. This issue was considered of great import because of the very large number of workers believed to be engaged in fabrication.

In March 1974, representatives of PVC producers, who are members of the Organization Resources Counselors (ORC), Occupational Safety and Health Standards Group, contacted ORC about the feasibility of a study of health risks to employees working with vinyl chloride and polyvinyl chloride. Since the National Institute for Occupational Safety and Health (NIOSH) was conducting a study of vinyl chloride and resin producing employees, the scope of the proposed ORC study was limited to employees of companies engaged in the fabrication of PVC resin into finished products. A number of alternative study designs was considered, and it was decided that a proportional mortality study would best meet the urgent need for information. The study concentrated on deaths occurring during the ten-year period 1964-1973 among active fabricating employees plus retirees. Since it was not possible to identify those employees with only vinyl chloride exposure, the study focused on deceased employees who worked anywhere in those plants where PVC fabrication was carried on. The primary objective of the study was to determine whether or not any angiosarcoma deaths had occurred among employees of the fabricators under study. A secondary objective was to examine the distribution of all deaths by cause.

The relatively few producers of vinyl chloride monomer and of PVC resin are generally medium to large companies. PVC fabricators, however, range from large plants of major companies to very small job shops. Even in a large plant, there may be few employees who are in the vicinity of PVC resins. The range of company plant size and number of exposed employees help to explain the wide range of estimates of total employment dependent upon PVC resins. Fabrication is geographically disbursed, with at least some operation in almost every state. Typical fabrication products include coated wire, upholstery fabrics, floor and wall coverings, pipe and other construction materials, toys, recreational equipment, phonograph records, containers and container lining, and a myriad of novelty items. Since the fabrication of PVC resin into finished products is often a part of diversified product lines in a plant, raw materials other than resin are utilized. Thus, employees may be exposed to toxic agents other than vinyl chloride. Consequently, in the current study, it is not possible to isolate only the effect of vinyl chloride. Some departures from expectation may be due to exposures to vinyl chloride, to one or more other agents, to some combination, or to employee characteristics other than occupation.

Materials and Methods

The decision to focus on a cross-sectional mortality study rather than on an historical cohort study derived from several considerations. First, the primary study objective was to determine relatively quickly whether or not any angiosarcoma deaths could be identified among the study group, and this was best accomplished by examining causes of death among relatively recent

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(i.e., past ten years) decedents. The desirability of identifying an historical cohort for follow-up was recognized, but it was determined that it would not be possible to identify clearly and completely the necessary cohort of workers within a reasonable period of time, if at all. As a consequence, this study is based upon 4,341 deaths which occurred during the period 1964-1973 among current or former employees of 17 companies engaged in PVC fabrication. A total of 55 plants supplied data on all identifiable deaths since, as was mentioned earlier, it was not possible to identify those employees with only vinyl chloride exposure for the study.

In order to be included in this study, a deceased employee fell into one of the following categories: (1) employee died while actively employed, (2) employee died after retiring from the company with retirement benefits, and (3) employee died after terminating employment but with vesting in a company-sponsored life insurance plan. Deaths occurring among former employees with less than the number of years necessary for insurance vesting were not included in plant records and were, therefore, not available for this study.

An attempt was made to compensate for at least some of the "leakage" due to employees leaving the industry prior to the time they were vested in any insurance program by using the following procedures. Once death records for a given company were identified, death certificates were obtained and separated into two groups as follows: (1) all deaths with cancer (ICDA 140-205 up to 1967; ICDA 140-209 for 1968 on), or liver disease (ICDA 580-586 up to 1967; ICDA 570-576 for 1968 on), or suspected liver condition mentioned on the death certificate; and (2) all deaths from causes other than cancer or liver disease. Death records mentioning cancer or liver disease and giving a hospital as place of death were segregated and sorted by hospital. Where there were several death records for a single hospital or several hospitals in the same area, arrangements were made for a Registered Records Administrator (RRA) to visit the hospitals, review medical records, contact the hospital pathologist and review pathology records to determine whether there were any angiosarcoma cases in the hospital's pathology records. If so, an attempt was made to determine whether or not the angiosarcoma possibly could be related to vinyl chloride exposure. This procedure enabled us to identify whether any employees, who had left the industry prior to vesting in an insurance program and remained in the local area, had died from angiosarcoma of the liver. The hospital inquiry procedures turned up five deaths from angiosarcoma of the liver; according to company employment records, none were employed at any time in PVC fabricating plants. These deaths were reported to OSHA, NIOSH, and CDC for inclusion in the nationwide angiosarcoma survey.

Death certificates not mentioning a hospital as a place of death required an additional step to determine whether death occurred in a hospital or if a recent hospitalization had occurred prior to death. The certifying physician was queried by mail for information on recent hospitalization of the decedent and whether there was any indication that he or she had cancer or liver disease. Additionally identified hospitals were contacted as above.

Originally, it was planned that death certificates would be obtained from life insurance carriers. In practice, both company and life insurance records were used because of record retention practices and retrieval problems in the insurance carriers. All available death certificates were examined by a trained nosologist for mention of angiosarcoma anywhere on the certificate, and no angiosarcomas were found on the death certificates. Underlying cause of death was classified according to the eighth revision of the International Classification of Diseases.[2]

Over the ten-year period under study, plant size was found to have changed drastically in many cases. In one instance, a plant employing 300 employees in 1973 employed fewer than 10 in 1964. At the other extreme, one plant employing 5,000 people in 1964 had only 2,000 in 1973. Some companies had gone out of business. Such developments show not only the rapid changes taking place but also the difficulty of determining average industry employment. The 17 companies covered in this report ranged from single plant, small companies (one with 70 employees) to multiplant large companies (one with over 7,000 employees). Average number of employees clustered between 300 and 500. Although total employment is difficult to determine precisely, it is estimated to have been between 65,000 and 70,000 at the end of 1973.

Since the population at risk could not be determined; mortality rates as measures of risk could not be calculated. Rather, results were summarized in terms of Proportionate Mortality Ratios (PMR) adjusted for the age distribution of the study group. The PMR uses relative frequencies of specific causes of death by age in a comparison population to obtain expected numbers of deaths from that cause in the study population. Selection of an appropriate comparison population poses some difficulties since it would be desirable to have a cause of death distribution for a similar group of workers dying during the same period, but not subjected to the factor under study. But such a comparison population was not available, and the study used mortality for the United States, specific for color and sex, for comparative purposes.[3] Despite recognized deficiencies, the PMR can provide clues on unusual distributions of causes of death where true rates cannot be calculated.

Results

Table 1 gives the distribution of deaths among the employees of the 17 PVC fabricators within each of the ten years. An increase in the proportion of deaths taking place in later years of the decade may reflect a variety of factors, such as an increasing employee population, less complete availability of records for earlier years (e.g., in one company, there were no records for the first four of the ten years), increase in duration of exposure, etc. However, there is no reason to believe that any unavailable death records for earlier years would be concentrated in a few causes and thereby bias the distribution of deaths for those years.

Table 1. — Distribution of Deaths Among Employees of 17 PVC Fabricators by Year of Death, 1964-1973

Year of Death	No.	Percent
1964	325	7.5
1965	345	8.0
1966	400	9.2
1967	429	9.9
1968	499	11.5
1969	449	10.3
1970	465	10.7
1971	471	10.9
1972	528	12.2
1973	430	9.9
Total	4341	100.0

Table 2. — Distribution of Deaths Among Employees of 17 PVC Fabricators by Color and Sex, 1964-1973.

Race	Total	Sex Male	Female	Unknown
Total	4366	3676	663	2
White	3849	3248	601	0
Nonwhite	204	180	24	0
Unknown	288	248	38	2

The distribution of deaths in the study group by race and sex is given in Table 2. Most deaths (84.7%) occurred among males. The vast majority (88.7%) of decedents were white and there were 288 (6.6%) for whom race could not be determined. Table 3 shows this distribution of deaths by age. For both white male and white female employees, more than half of the deaths occurred among those aged 65 and over (58.1% and 51.9% for white men and white women, respectively). The corresponding proportions of deaths which occurred after age 65 in the United States population in 1968 were 59% and 72%, respectively). The higher proportion of deaths among white women over 65 in the U.S. population compared to the employee population may indicate that relatively fewer women work to retirement age than do men. While the numbers of deaths among nonwhite employees are too small for any definite conclusions, the distribution of deaths by age among nonwhite men is roughly comparable to that for the total United States.

Tables 4 and 5 show the distribution of deaths for selected causes by sex for whites and nonwhites, respectively. Among white men, nearly 60% of the deaths are from diseases of the circulatory system (ICDA 390-458) and 20% are deaths from cancer (ICDA 140-209). The corresponding percentages for the total U.S. population of white males in 1968 (midpoint of the study period) were 54% for diseases of the circulatory system and 16% for cancer. Digestive and respiratory cancers account for somewhat less than two-thirds of all cancer deaths among the white males in the study group as compared to about 59% of all cancer deaths among U.S. white males in 1968. For white women, over 46% of the deaths are from diseases of the circulatory system (compared to 57% for all U.S. white women in 1968), and 30% were from cancer (compared to 18% for all U.S. white women in 1968). Somewhat over half of the cancer deaths among white women in the study were from cancers of the breast and digestive system, about the same proportion as for all U.S. white women in 1968. About two-thirds of the deaths for both nonwhite men and women were from diseases of the circulatory system and from cancer. The numbers of deaths for most causes among nonwhites, however, are quite small making interpretation difficult and are presented mainly for completeness.

Age-adjusted PMRs for white male and white female employees of the 17 PVC fabricators are presented in Table 6 for selected causes of death. There were no similar analyses for nonwhites because for nearly all causes, the numbers of deaths were too small to produce stable PMRs. Expected numbers of deaths have been calculated on the basis of the sex-cause-age specific distribution of deaths among U.S. whites in 1968 applied to the total number of deaths by age among white men or white women in the study group. The midpoint of the study period (1968) was selected for the standard, since it is representative of the study period and provides U.S. mortality data coded according to the eighth revision of the International Classification of Diseases. *Expected numbers* are deaths for individual causes to be expected in the study group if the proportion of total deaths ascribed to a given cause were the same as for the corresponding U.S. race-sex group, while accounting for differences between the age distributions of deaths in the study groups and deaths for the United States. A PMR larger than unity would indicate that the relative proportion of mortality from that particular cause in the study population is higher than would be expected based on the 1968 U.S. mortality experience. Due to the nature of the data, formal significance tests and interpretation in probabilistic terms are deemed inappropriate.

In addition to the numerical value of the PMR itself, the observed number of deaths is also of interest. The larger the number of deaths observed, the more reliable the PMR. There were two deaths of unknown age among the white males, one a digestive cancer (ICDA 153) and one an unspecified cancer (ICDA 199). These were included in the age groups with the lowest relative frequency for those causes, that is, less than 35 years for total cancer and digestive cancer and 65 and over for other and unspecified cancer. Such an assignment has a trivial effect on the expectation but is the most conservative way of handling these unknowns, since it serves to increase the expectation (and hence lower the PMR) by the least amount.

Based upon both the number of deaths and the value of the PMR, there seems to be an important excess in total cancer mortality among the white males in the study group. The distribution by specific cancer site suggests that any excess appears to be con-

Table 3. — Distribution of Deaths Among Employees of 17 PVC Fabricators by Age, Color, Sex, 1964-1973.

	All Ages		Age Under 35		35-44		45-54		55-64		65 & over		Unknown	
Color, Sex	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
White														
Male	3248	100	107	3.3	136	4.2	365	11.2	752	23.2	1886	58.1	2	0.1
Female	601	100	24	4.0	42	7.0	100	16.6	123	20.5	312	51.9	0	0
Nonwhite														
Male	180	100	21	11.7	24	13.3	28	15.6	39	21.7	68	37.8	0	0
Female	24	100	6	25.0	2	8.3	5	20.8	6	25.0	5	20.8	0	0
Unknown														
Male	248	100	20	8.1	5	2.0	32	12.9	48	19.4	131	52.8	12	4.8
Female	38	100	1	2.6	5	13.2	4	10.5	8	21.1	18	47.4	2	5.3
Unknown	2	100	1	50.0	0	0	0	0	0	0	0	0	1	50.0

liver. However, there was a suggestion that cancers of the lung and brain also appeared with excess frequency. The current study, while suggesting an excess in total cancer, particularly digestive cancer, does not clearly point to marked excesses for cancers of the liver, lung, and brain among white men, although the PMRs for these cancers are greater than one. The observed-to-expected PMRs reported by Monson for vascular lesions affecting the central nervous system, circulatory diseases, and external causes are similar to those reported here.

Tabershaw and Gaffey, in a study of workers engaged in the manufacture of vinyl chloride and its polymers, conclude that no specific cause of death was statistically significantly greater than expectations based upon Standardized Mortality Ratios (SMRs) using the U.S. male population as the standard.[9] By other criteria, however, the authors conclude there may be an excess risk for mortality from digestive cancer, respiratory cancer, cancer of other and unspecified sites, and lymphomas. At lower exposure levels, they suggest some excess for cancers of the buccal cavity and cancers of the other and unspecified sites.

The current study would seem to indicate that excesses of mortality from cancer of the digestive system are not sex-specific and are not limited to liver cancer. The majority of the PMRs for cancer among both white men and white women are in excess of unity. Such results must be interpreted with caution but, since they appear to be consistent with previously studied workers, they suggest the need for continued investigation.

Summary

Results of a study of 4,341 deaths occurring among current and former employees of 17 PVC fabricators during the period 1964-1973 are presented. The study was carried out to determine whether any angiosarcoma deaths had occurred among employees of these fabricators and to examine the distribution of deaths by cause. No angiosarcoma deaths were found among the study population. Distributions by cause of death among white male and white female employees were compared with those for the entire U.S., specific for color and sex and adjusted for age by means of Proportionate Mortality Ratios. There appears to be an important excess in total cancer mortality among both white male and white female employees with digestive cancer, particularly that of the intestine, contributing to the excess. Among the women employees, cancers of the breast and urinary organs may also be in excess. No excesses were found for diseases of the circulatory system. There were deficits in mortality from cirrhosis of the liver among both male and female employees and a deficit in accidents, poisonings, and violence among men. The use of the Proportionate Mortality Ratio based on an external standard requires caution in interpreting these results, but the need for further investigations is indicated.

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Table 4. — Distribution of Deaths from Selected Causes Among Employees of 17 PVC Fabricators by Sex, White Only, 1964-1973.

Cause of Death	ICDA 8th Rev.	Male No.	Male %	Female No.	Female %
All Causes		3248	100.00	601	100.00
All Cancers	140-209	666	20.50	181	30.12
Buccal Cavity and Pharynx	140-149	15	0.46	3	0.50
Digestive System	150-159	209	6.43	53	8.82
Stomach	151	41	1.26	8	1.33
Intestine	153	73	2.25	24	3.99
Rectum	154	25	0.77	8	1.33
Liver	155	6	0.18	0	0
Respiratory System	160-163	205	6.31	12	2.00
Lung	162	193	5.94	12	2.00
Bone, Connective Tissue, Skin, Breast	170-174	24	0.74	51	8.49
Breast	174	0	—	44	7.32
Genital Organs	180-187	44	1.35	19	3.16
Urinary Organs	188-189	36	1.11	11	1.83
Brain & Other Nervous System	191-192	16	0.49	4	0.67
Other & Unspecified	190, 193-199	56	1.72	18	3.00
Lymphomas	200-203, 208-209	42	1.29	9	1.50
Leukemias	204-207	19	0.58	1	0.17
Diabetes	250	42	1.29	11	1.83
Diseases of the Circulatory System	390-458	1931	59.45	281	46.76
Cerebrovascular Disease	430-438	289	8.90	66	10.98
Cirrhosis of Liver	571	42	1.29	3	0.50
Cholelithiasis, Cholecystitis and Cholangitis	574-575	7	0.22	3	0.50
Accidents, Poisoning, and Violence	E800-E999	188	5.79	48	7.99
Accidents	E800-E949	134	4.13	38	6.32
Suicide	E950-E959	40	1.23	2	0.33
All Other Causes (Residual)		372	11.45	74	12.31

Table 5. — Distribution of Deaths from Selected Causes Among Employees of 17 PVC Fabricators by Sex, Nonwhite Only, 1964-1973.

Cause of Death	ICDA 8th Rev.	Male No.	Male %	Female No.	Female %
All Causes		180	100.00	24	100.00
All Cancers	140-209	39	21.66	8	33.33
Buccal Cavity and Pharynx	140-149	0	0	0	0
Digestive System	150-159	13	7.22	4	16.67
Stomach	151	3	1.67	0	0
Intestine	153	2	1.11	1	4.16
Rectum	154	1	0.56	0	0
Liver	155	1	0.56	0	0
Respiratory System	160-163	7	3.89	0	0
Lung	162	7	3.89	0	0
Bone, Connective Tissue, Skin, Breast	170-174	0	0	3	12.50
Breast	174	0	0	3	12.50
Genital Organs	180-187	4	2.22	0	0
Urinary Organs	188-189	3	1.67	0	0
Brain & Other Nervous System	191-192	1	0.56	0	0
Other & Unspecified	190, 193-199	6	3.33	0	0
Lymphomas	200-203, 208-209	4	2.22	0	0
Leukemias	204-207	2	1.11	1	4.16
Diabetes	250	2	1.11	0	0
Diseases of the Circulatory System	390-458	81	45.00	8	33.33
Cerebrovascular Disease	430-438	19	10.56	3	12.50
Cirrhosis of Liver	571	3	1.67	1	4.16
Cholelithiasis, Cholecystitis, & Cholangitis	574-575	0	0	0	0
Accidents, Poisoning, & Violence	E800-E999	33	18.33	3	12.50
Accidents	E800-E949	17	9.44	1	4.16
Suicide	E950-E959	2	1.11	0	0
All Other Causes (Residual)		22	12.22	4	16.67

centrated in digestive system cancer, given the large number of deaths (31% of all cancer deaths). For each of the sites within the digestive system, observed numbers of deaths are greater than expected. Although, except for intestinal cancer, the observed numbers of deaths are small. The PMR for liver cancer is rather high, but a definite conclusion is difficult with only six observed deaths. On the other hand, the PMR for cirrhosis of the liver suggests a deficit in mortality from that cause.

For white women, the PMR for total cancer appears high, as it did for white men, with cancer of the digestive system and, perhaps, cancer of the breast contributing a fair amount to the excess. The PMRs for individual sites within the digestive system are based upon small numbers but suggest an increase in intestinal cancer. The PMR for urinary cancer, though based upon only 11 deaths, seems strikingly high and may be an indication for further investigation. On the other hand, in contrast to the observation in white men, the PMR for respiratory cancer among white women is very close to unity. Similar to the observation in white men, mortality from cirrhosis of the liver seems to be in deficit, but the corresponding observed number of deaths is quite small. Among both white male and female employees, diseases of the circulatory system account for a large percentage of total deaths. In each case, observed numbers of deaths are close to expected. There appears to be a somewhat different pattern among men and women for deaths due to accidents, poisonings, violence with the number of deaths somewhat low among men and high among women.

There were 39 cancer deaths among nonwhite men, somewhat greater than expectation, although the numbers by site are too small for meaningful analysis. Mortality from cerebrovascular disease appeared high (PMR = 2.11) but the finding was based upon only 19 deaths.

Discussion

The present study was designed with two objectives. The first was to determine whether or not any angiosarcoma deaths had

Table 6. — Observed and Expected Deaths for Selected Causes Among Employees of 17 PVC Fabricators by Sex, White Only, 1964-1973.

Cause of Death	ICDA 8th Rev.	Male			Female		
		Observed	Expected	PMR*	Observed	Expected	PMR*
All Cancers	140-209	666	561.997	1.19	181	137.699	1.31
Buccal Cavity and Pharynx	140-149	15	16.875	0.89	3	1.896	1.58
Digestive System	150-159	209	162.143	1.29	53	35.342	1.50
Stomach	151	41	31.507	1.30	8	4.981	1.61
Intestine	153	73	52.528	1.39	24	15.344	1.56
Rectum	154	25	19.631	1.27	8	3.877	2.06
Liver	155	6	4.190	1.43	0	0.633	—
Respiratory System	160-163	205	176.657	1.16	12	11.888	1.00
Lung	162	193	165.566	1.17	12	11.224	1.07
Bone, Connective Tissue, Skin, Breast	170-174	24	15.117	1.59	51	35.661	1.43
Breast	174	0	—	—	44	32.397	1.36
Genital Organs	180-187	44	52.828	0.83	19	23.297	0.82
Urinary Organs	188-189	36	33.131	1.09	11	4.537	2.42
Brain & Other Nervous System	191-192	16	13.885	1.15	4	3.499	1.14
Other & Unspecified	190, 193-199	56	34.607	1.62	18	9.622	1.87
Lymphomas	200-203, 208-209	42	32.382	1.30	9	7.631	1.18
Leukemias	204-207	19	23.364	0.81	1	5.005	0.20
Diabetes	250	42	49.600	0.85	11	15.436	0.71
Diseases of the Circulatory System	390-458	1931	1832.515	1.05	281	309.232	0.91
Cerebrovascular Disease	430-438	289	292.074	0.99	66	71.965	0.92
Cirrhosis of Liver	571	42	62.821	0.67	3	12.343	0.24
Cholelithiasis, Cholecystitis, and Cholangitis	574-575	7	6.349	1.10	3	1.783	1.68
Accidents, Poisoning, and Violence	E800-E999	188	265.548	0.71	48	40.855	1.17
Accidents	E800-E949	134	189.268	0.71	38	27.931	1.36
Suicide	E950-E959	40	52.325	0.76	2	9.171	0.22

*PMR is the ratio of observed to expected where the expected number is calculated on the basis of the distribution of deaths for the total U.S. in 1968 specific for color, sex, cause, and age.

occurred among employees of the PVC fabricators under study. Since no angiosarcoma deaths were found among the employees studied, the first question has an unequivocal answer. A secondary objective was that of examining the distribution of deaths by cause among the employees under study. Implicit in that objective is the question of whether or not that distribution is, in some sense, unusual. There is no unequivocal answer to the latter question. Whether or not an observed distribution of causes of death is unusual clearly relates to the standard or comparison population as well as the analytic methodology.[4]

On the basis of a proportionate mortality analysis, there appear to be excesses in total cancer mortality among both white men and white women in the study, when compared to the distributions of deaths for the total United States specific for color and sex and adjusted for age. Excesses in cancer mortality appear concentrated in cancers of the digestive system and, in particular, in cancers of the intestine for both men and women. In addition, there is a suggestion that mortality from cancer of the breast and urinary organs among white women employees is higher than that for the total U.S. There are, however, several reasons why definitive interpretation is difficult. It has, for example, been suggested that a Proportionate Mortality Ratio based on an external population may not be sufficiently discriminating in screening for potential hazards.[5] In addition, an analysis using PMRs fails to take account of the absolute risk of dying in the population under study.[6] Further, a number of studies have suggested an overall favorable mortality for industrial working populations, even in those where well-defined hazards increase risk for a specific cause.[7,8] Factors such as these are meant to suggest that proportionate mortality analysis must be interpreted cautiously, with the intention of providing leads for further investigation.

Results consistent with those of previously published studies would be of particular interest. With no comparable working populations in the fabrication industry, potential contrasts may be found in studies of vinyl chloride workers. Monson, et al, provided a proportionate mortality analysis of 161 deceased workers (all presumably white males) in two plants, one where vinyl chloride monomer is produced and one where it is polymerized into polyvinyl chloride.[6] Results of that study suggest a possible excess in total cancer mortality, primarily cancer of the

File - PVC

Polyvinyl Chloride Pneumoconiosis: Epidemiological Study of Exposed Workers

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Among 1216 workers who were employed in a polyvinyl chloride production factory and who had had no previous dust exposure elsewhere, 20 cases of pneumoconiosis were found. Chest x-ray abnormalities were characterized by limited profusion, irregular type and low gravity. All 20 workers had been exposed to high PVC dust levels. The chest x-ray changes were observed after a minimum exposure of five years and, in a small percentage of cases, were associated with slight restrictive respiratory function impairments. Moreover, in the whole group of workers 388 cases (31.9%) were found with non-specific x-ray abnormalities mainly related to age and smoking.

Polyvinyl chloride (PVC) dust is particularly relevant to a consideration of the anatomical, clinical and radiological signs of pneumoconiosis found in workers exposed to "inert" dusts because of the high annual production of PVC and the number of exposed workers.

Within the framework of a national survey on vinyl chloride hazards to humans, co-ordinated by the Chemical Workers Unions, the authors examined the working population of plants producing PVC in Porto Marghera, Italy. One group of workers was exposed to PVC dust, another group worked in departments polluted only by vinyl chloride monomer (VCM).

The characteristics and prevalence of pulmonary radiological abnormalities found are reported and their pathogenic mechanism is discussed in this article.

Methods and Population

Environmental dust samples were collected and both concentration in air and particle size were measured. In the drying, sacking and blending departments, PVC dust concentrations were higher than the TLV (10 mg/m³ of total dust) in about 60% of the samples. In the polymerization departments, no concentration higher than the TLV was found. In the samples taken, particles with diameters of 1 μm to 5 μm constituted 4.5% to 30.9% of total dust weight.

All the workers answered the European Coal and Steel Community (ECSC) questionnaire for chronic bronchitis and emphysema,[1] and were submitted to chest x-ray (according to ILO standards) and spirographic examination (Godart-Expirograph, Bilthoven, Holland). Chest x-ray films were read by two independent physicians utilizing the *ILO/UC Pneumoconiosis Classification*, 1971.[2] For statistical analysis, a consensus reading was used. For each worker examined, present and past working histories were carefully recorded and particular consideration was given to previous dust exposure. Of the total, 1,216 subjects had had no past exposure to organic or inorganic dusts, 731 had been exposed to PVC dust (employed in drying, sacking and blending of polymer), and 485 had been exposed to monomer alone.

Results

Table 1 shows the mean and standard deviation of age and of length of exposure, the number of subjects and the percentage of smokers in the two groups, those exposed to PVC dust and those not exposed. There are no significant differences in age and smoking habits, but the duration of exposure is higher in the workers not exposed to dust.

In 20 subjects (1.6%), we diagnosed a typical pneumoconiosis, i.e., chest x-ray changes (irregular opacities or frankly micronodular images) of at least class 1 profusion according to the ILO/UC classification. The

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Table 1. — Age, Exposure, Number of Subjects and Percentage of Smokers in PVC Dust Exposed and Non-Exposed Groups.

	Age (Years)		Exposure (Years)		No. of	% of
	Mean	S.D.	Mean	S.D.	Subjects	Smokers
PVC dust exposed group	37.7	8.8	6.1	4.0	731	73.9
PVC dust non-exposed group	35.7	8.5	8.6	4.5	485	68.7

mean age of this group was 44.9 (± 5.2) years and the mean length of exposure was 11.6 (± 5.4) years, 16 subjects (80%) were either smokers or ex-smokers.

Table 2 summarizes the distribution of cases in relation to age and length of exposure. In all age groups there is an increase of disease prevalence associated with increasing length of exposure. In the case of x-ray changes, 16 subjects had class 1/0 profusion; two cases, class 1/1; one case, class 2/1; and one case, class 2/2. In spite of age and the considerable exposure, the majority of cases observed were in a low profusion category, thus indicating a slow evolution of the disease. The changes were characterized by irregular opacities: ten cases were type "s"; three cases, type "t"; six cases, type "p"; and one case, type "r." The opacities were diffused, mainly over median lobe areas. Two subjects showed slight restrictive spirographic impairment. All had had jobs which involved high airborne dust levels (mostly drying and sacking) for at least five years. None of the 20 subjects was in a group unexposed to dust. None of them had experienced previous occupational exposure to organic or inorganic dusts. We considered the above alterations to be PVC pneumoconiosis.

In 388 subjects (31.9%) we found slight chest x-ray alterations consisting of linear or irregular vanishing opacities, or both, classified as class 0/1 profusion; the remaining 808 subjects were class 0/0.

Table 3 reports the total population distribution, excluding 20 subjects with PVC pneumoconiosis. Results are presented in a two-way table — each entry reports the number of observations. Samples are classified according to age (three classes) and polyvinyl chloride dust exposure: "PVC +" represents presence and "PVC −," absence. In the table, "x-ray +" indicates the classes with class 0/1 profusion. To assess the influence of both risk indicators we performed a two-way analysis of variance for proportions (Snedecor and Cochran).[3] The column mean is adjusted for row effects and vice versa. We also tested whether row and column effects were additive or whether interaction was present. The results (Table 4) show that both age and exposure were significant factors influencing x-ray abnormalities — since the interaction is not significant, the effects are simply additive.

The square of a multiple-partial association coefficient for qualitative data was calculated to measure the degree of association between the dependent variable (x-ray changes) and each of the two predictor variables (age and exposure).[4] Age and exposure are alternately held constant. Age is a most important factor. When exposure is held constant, 33.2% of the x-ray changes are shown to depend upon age; when age is held constant, 6.5% are shown to depend upon exposure.

Table 5 summarizes the distribution of cases (same subjects as Table 3) according to smoking habits in workers exposed and not exposed to PVC dust. In Table 6, the two-way analysis of variance for proportions shows that both risk indicators have a significant influence on chest abnormalities.

There is no interaction of factors. Habitual smoking plays a major role and, when exposure is held constant, is shown to be responsible for 17.1% of the changes. When smoking habits are held constant, exposure to PVC dust is shown to be responsible for 8.9% of the x-ray abnormalities.

Discussion

X-ray changes of at least class 1 profusion, found in 20 subjects, are considered PVC-induced pneumoconiosis. This claim is based on the following: (1) Reading of the chest films was performed by two independent physicians, who were not informed of the age, job, length of exposure or clinical history of workers. A consensus reading was required for the pneumoconiosis diagnosis. (2) Special attention was given to the absence of any previous occupational exposure to organic or inorganic dusts. (3) The changes were found in workers who had experienced prolonged exposure in departments with demonstrated PVC dust pollution. The length of exposure was about 12 years on the average and never less than five. No radiographic signs of pneumoconiosis were found in subjects working in departments free of PVC dust, although the average period of exposure was longer

Table 2. — Distribution of PVC Pneumoconiosis in Age and Exposure Classes (The percentage on the group of same age and exposure is shown in parentheses).

PVC Dust Exposure (Years)	Age (Years) ⩽ 30	31-40	41-50	> 50
< 5	—	—	—	—
5-10	—	2 (2.4)	5 (8.3)	1 (5.9)
> 10	—	2 (3.8)	8 (9.0)	2 (9.5)

Table 3. — Distribution of Cases with Class 0/1 and 0/0 Profusion According to Age and PVC Dust Exposure.

	Age (Years) ⩽ 30	31-40	41-50	> 50
PVC +				
X-ray +	20	78	123	35
X-ray -	133	197	108	17
PVC -				
X-ray +	17	45	55	15
X-ray -	119	158	67	9

Table 4. — Two-Way Analysis of Variance for Proportions (Same cases as in Table 3).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Age	3	30.9713	10.3238	53.81*
PVC dust exposure	1	0.7845	0.7845	4.09†
Interaction	3	0.9882	0.3294	1.72
Error	1186	227.9403	0.1919	

*$p < 0.01$
†$p < 0.05$

Table 5. — Distribution of Cases with Class 0/1 and 0/0 Profusion According to Smoking and PVC Dust Exposure.

	Nonsmokers	Smokers
PVC +		
X-ray +	40	216
X-ray -	147	308
PVC -		
X-ray +	25	107
X-ray -	127	226

in these workers (Table 1).

Previous experimental data on animals and reports of human lung biopsy indicated the possibility that the impairments described above can be attributed to PVC dust inhalation. In 1970, Szende et al[5] reported a case of pneumoconiosis in a worker exposed to PVC dust. Chest x-ray films showed small patches which became denser toward the hilum. Biopsy revealed multiple granulomatous centers consisting of foreign amorphous material surrounded by granulation tissue composed of histiocytes, lymphocytes, plasma cells, eosinophils and foreign body giant cells. Such centers were associated with moderate diffuse fibrosis.

A histiocytic-macrophage reaction in alveolar septa, observed by Frongia et al[6] in guinea pigs exposed to PVC dust in a sacking department, developed into lesions with multiple granulomatous centers with giant cells during the course of exposure. Rats exposed to a similar working environment developed marked thickening of interalveolar septa with an evolution similar to that in the guinea pigs.

Such experimental and pathologic data confirm the results of this epidemiological study. Lung changes are directly related to PVC dust while VCM exposure alone fails to cause these changes. Therefore, unlike Lilis et al,[7] we believe that pulmonary changes are not pathogenically similar to other vinyl chloride induced abnormalities (fibrosis of the liver, scleroderma-like skin changes, peripheral vascular damage).

In the present study there was only a 1.6% prevalence of pneumoconiosis in a total population of 1,216 subjects. Nevertheless, in workers exposed to effective risk of pneumoconiosis (731 subjects) the prevalence rose to 2.7%. Waxweiler et al[8] reported pulmonary fibrotic changes associated with respiratory function impairments in 96 subjects exposed to PVC dust. Lilis et al[7] studied the chest x-ray films and changes in respiratory function of groups of PVC production workers who had experienced exposure of different degree and length. They found a 4.3% to 22.7% prevalence of chest x-ray changes (small, linear, reticular and/or rounded opacities) and spirographic impairments related to the duration of exposure and to the presence of chest x-ray changes. As these authors did not employ either the ILO/UC International Classification or any other, no comparison concerning the reported prevalence can be made with the present data.

Apart from 20 cases of pneumoconiosis, mild nonspecific alterations (profusion of 0/1 class) were found both in the group exposed to PVC dust and in the group exposed to VCM alone. Such changes are related mainly to age and smoking habits, and the role of exposure is minor.

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Table 6. — Two-Way Analysis of Variance for Proportions (Same cases as in Table 5).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Smoking	1	7.8850	7.8850	37.31*
PVC dust exposure	1	1.7847	1.7847	8.44*
Interaction	1	0.1023	0.1023	<1
Error	1192	251.9125	0.2113	

*$p < 0.01$