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Asbestos-Related Disease in Custodial and Building Maintenance Workers from a Large Municipal School District

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Asbestos was used extensively in school and other construction over the several decades prior to 1978, when its use was severely restricted by the U.S. Environmental Protection Agency (EPA). Contamination of the environment in public school buildings can occur not only during construction and demolition, but also throughout the existence of these buildings, on account of friable asbestos-containing materials (ACM) such as spray-on acoustical insulation and decoration, thermal insulation applied around steam pipes and boilers, and fire-proofing of structural beams. On the basis of a survey of the nation's public schools, the EPA estimated in 1982 that approximately 8,600 schools had friable ACM in place.[1] The EPA has also estimated that approximately 23,000 janitorial and maintenance workers are potentially exposed to airborne asbestos in these schools.[2]

Asbestos fibers are released from friable ACM as a result of general deterioration of the material, or as a result of contact or impact with the material during activity within the contaminated structure. Once released, fibers settle slowly but can be resuspended with further activity in the structure. Sawyer and Spooner have measured concentrations of fibers released by routine maintenance activities in various buildings including schools.[3] Custodial activity (e.g., sweeping and vacuuming) in an urban grammar school with an exposed ceiling containing 15% chrysotile was associated with a mean airborne asbestos concentration of 643 ng/m^3, with a range of 186 to 1,100 ng/m^3. The EPA has reported the results of air monitoring for asbestos fiber concentration in a number of public schools. In 10 schools evaluated because of visibly damaged areas of sprayed-on chrysotile asbestos during the late 1970s, the airborne concentrations ranged from 9 to 1,950 ng/m^3 with a mean of 217 ng/m^3 (Ref. 4). Thus, there appears to have been a potential for occupational exposure to asbestos dust of public school custodial and building maintenance employees.

We hypothesized that occupational exposure to asbestos of many public school employees was of sufficient intensity and duration to have induced pulmonary parenchymal and pleural fibrosis. We were able to collect descriptive data relevant to this hypothesis by studying a group of public school custodial and

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building maintenance workers who were known to have been exposed to ACM in school buildings.

METHODS

In 1980, a large urban school district surveyed its school buildings for ACM as mandated by the EPA. At least 80 percent of the approximately 750 buildings surveyed were noted to have ACM. After an inspection of the conditions of exposure to asbestos of maintenance employees in several of these buildings in 1981, the California Occupational Safety and Health Administration (CAL/OSHA) required the school district to establish a medical surveillance program for asbestos-related disease. One of the authors (J.B.) assumed responsibility for the surveillance program in May 1983. During the first two years of this program (i.e., from 1981 to 1983), 35 workers were diagnosed as having parenchymal asbestosis and/or asbestos-related pleural disease. These 35 workers were excluded from further participation in the school district's medical surveillance program and are not considered in this report.

Primarily on the basis of job classification, the school district had determined by 1983 that approximately 900 of its employees had likely been exposed to asbestos dust while working for the district. These employees were required to participate in the asbestos-related disease medical surveillance program. The protocol used in this program included the following components: questionnaire administration regarding occupational/exposure history, medical history, and respiratory symptoms; a limited physical examination; spirometry; and chest X-rays. This preliminary report is concerned with the results of 673 participants in the program from May 1983 through June 1985 for whom adequate data are available for analysis.

The self-administered questionnaire asked for a complete occupational history, including all jobs held prior to school district employment. The completed questionnaire was reviewed with the participant by the examining physician. An effort to record likely exposure to asbestos prior to employment with the school district was made. Smoking history and respiratory symptoms questions were modified from those of the American Thoracic Society (ATS) Epidemiology Standardization Project.[5] The limited physical examination was conducted by a physician (usually one of us [J.B.]) and included measurement of blood pressure and pulse, examination of the oropharynx, cervical and axillary lymph nodes, chest, heart, extremities, and rectal examination with stool guaiac test.

Spirometry was performed by National Institute for Occupational Safety and Health (NIOSH)–certified technicians according to ATS performance criteria[6] using a volume-displacement spirometer (Model VS 400, Puritan-Bennett, Wilmington, MA). The spirometer was calibrated by a 3-liter syringe at the start of each day that testing was performed. Each participant's height was measured prior to spirometry. Each participant performed a minimum of three forced expiratory maneuvers in a sitting position with a noseclip in place. Values for forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and forced expiratory flow rate between 25% and 75% of vital capacity (FEF_{25-75}) were corrected to body temperature and pressure, saturated with water vapor. For data analysis, the maximum FVC and FEV_1 values were used, regardless of curve of origin. The FEF_{25-75} was taken from the curve giving the largest sum of FVC and FEV_1. Predicted values were calculated by using the regression equation of Morris and coworkers.[7] The predicted values for blacks were then multiplied by 0.85

(Ref. 8). No correction factor was applied to the predicted values for Hispanics, Asians, or Native Americans. Percents of predicted values were calculated for FVC, FEV_1, and FEF_{25-75}.

Chest radiographs (41 × 43 cm) were taken in the posteroanterior and bilateral anterior oblique projections at full inspiration, 110 kVp, and a standard distance of 183 cm. The films were independently interpreted by three of a panel of four NIOSH-certified "B" readers (including one of the authors (J.B.) and Drs. E. Nicholas Sargent, J. Gordonson, and Oscar J. Balchum) according to the International Labour Office (ILO) 1980 system of classification.[9] For data analysis, the ILO profusion scores were assigned values from 1 to 12 (i.e., 0/0 = 1, 0/1 = 2, 1/0 = 3, etc.), and ratings of pleural thickening were evaluated as to whether there were unilateral or bilateral findings. The mean of the three independent profusion scores was used and parenchymal asbestosis was considered present when the mean score was ≥ 3 (i.e., ≥1/0 by the ILO classification). Asbestos-related pleural disease was arbitrarily defined as present when two of the three readers recorded the presence of bilateral pleural thickening.

STATISTICAL ANALYSIS

Standard univariate procedures were used to analyze the distribution of relevant variables. For those continuous variables with different distributions for cases of asbestos-related disease and controls, the *t* test was used to determine whether differences in mean values were statistically significant. A p value ≤ 0.05 was considered significant, using a two-tailed alternative hypothesis. Logistic regression analysis was used to assess the effect of variables such as cigarette smoking status and length of employment with the school district on the probability of having asbestos-related disease.

RESULTS

The demographic characteristics of the 673 school district employees are presented in TABLE 1. The occupational categories used by the school district to classify these employees and the number of employees in each category are listed

TABLE 1. Demographic Characteristics of School District Employees (n = 673)

Mean age (yr)	48.6
Male (%)	97.2
Race or ethnic group	
White (%)	53.8
Black (%)	29.0
Hispanic (%)	12.8
Other (%)	4.4
Mean years employed by school district	15.6
Previous exposure (%)	34.6
Smoking history	
Never (%)	33.7
Former (%)	36.9
Current (%)	29.4

TABLE 2. School District Occupational Classifications

Classification	Number
Plumber	96
Heating, ventilation, and air-conditioning worker	67
Building engineer	48
Carpenter	45
Electrician	45
Custodian	42
Plant manager	40
Painter	37
Auto mechanic	34
Construction trade helper	32
Sheet-metal worker	21
Construction inspector	21
Other construction trades	52
Miscellaneous	93

in TABLE 2. Job classifications included in the "miscellaneous" category are driver, electronic technician, environmental health and safety technician, executive, fire extinguisher technician, machinist, pest-control technician, playground-gym equipment installer, and stock clerk.

The prevalence of symptoms of chronic bronchitis for the 673 participants was 12 percent. The prevalence of wheezing was 20 percent. While moderate to severe grades of dyspnea were rare, 27 percent of the employees reported experiencing dyspnea on climbing one flight of stairs. Physical examination findings consistent with asbestosis were rare. Only 1% of participants had bilateral late-inspiratory crackles which did not clear with cough and only one participant was noted to have clubbing.

Since 97 percent of the 673 school district employees studied were male, the females were excluded from the subsequent analyses. Because our hypothesis was that school district exposure to dust from asbestos-containing materials is capable of causing asbestos-related disease, employees who reported a history of asbestos exposure prior to their employment with the school district were also excluded from the subsequent analyses. The demographic characteristics of the 422 participants (65 percent) who reported no previous exposure to asbestos are presented in TABLE 3. The radiographic findings for these participants are summarized in TABLE 4. Because parenchymal asbestosis and asbestos-related pleural disease are usually not radiographically manifest until long after onset of exposure, we elected to focus on the 315 participants with at least 10 years of employment with the school district. Thirty-six, or 11.4 percent, of the participants with no previous history of exposure to asbestos *and* with at least 10 years of school district employment had evidence of asbestos-related disease. The prevalence of parenchymal asbestosis and asbestos-related pleural disease among the 36 cases is shown in TABLE 5. The 36 participants with asbestos-related disease were older, smoked more, and had worked longer for the school district than the other 279 participants (controls) with at least 10 years of employment with the district (TABLE 6). They also had significantly lower mean values for percent of predicted FEV_1, FVC, and FEF_{25-75}. The mean values for the FEV_1/FVC, as percent of predicted, were not significantly different and there was no evidence that the 36 cases were characterized by large airway obstruction. Considering only the 23

TABLE 3. Demographic Characteristics of Male School District Employees Not Previously Exposed to Asbestos (n = 422)

	Percentage
Age	
≤40	30.3
41–50	23.2
51–60	35.8
≥61	10.7
Length of school district employment	
≤5 yr	12.1
6–10 yr	18.5
11–15 yr	19.2
>15 yr	50.2
Smoking history	
Never	27.7
Former	36.5
Current	35.8

TABLE 4. Radiographic Findings in 422 School District Employees, May 1983–June 1985

	Percentage
Parenchymal involvement	
ILO profusion grade	
0/0	68.7
0/1	25.4
1/0	4.5
1/1	0.7
≥1/2	0.7
Pleural involvement	
Unilateral	2.1
Bilateral	4.7
Circumscribed plaques	6.9
Diffuse	0.7

TABLE 5. Asbestos-Related Disease among Male School District Employees Not Previously Exposed *and* with ≥10 Years of Employment (n = 315)

	Number (%)
Without asbestos-related disease (controls)	279 (88.6)
With asbestos-related disease (cases)	36 (11.4)
Parenchymal involvement only	18 (5.7)
Pleural involvement only	13 (4.1)
Parenchymal and pleural involvement	5 (1.6)

TABLE 6. Asbestos-Related Disease Cases Compared with Controls[a]

	Cases (n = 36)	Controls (n = 279)
Age (yr)	56	48.8[b]
Smoking (pack–years)	22.3	12.4[b]
Length of employment (yr)	22.5	19.9[b]
Spirometric findings (% predicted[c])		
FEV_1	91.8	104[b]
FVC	89.5	100.2[b]
FEV_1/FVC	102.3	103.7
FEF_{25-75}	69.9	86.8[b]

[a] See Table 5.
[b] $p < 0.05$.
[c] Calculated by the regression equation of Morris *et al.*[7]

cases with parenchymal asbestosis, mean values for FEV_1, FVC, and FEF_{25-75} remained significantly lower compared to the controls. Considering only the 18 cases with asbestos-related pleural disease, mean values were significantly lower for FEV_1 and FVC, but not for FEF_{25-75}.

When the 422 participants without previous exposure to asbestos were stratified by ILO profusion grade, there was a clear trend toward decreased mean values for percent of predicted FVC (TABLE 7) and FEV_1 (not shown) with increasing profusion score. To evaluate the association of smoking with asbestos-related disease, we initially stratified these 422 participants by their radiographic findings and noted that the persons with parenchymal disease, but not those with pleural disease, had a greater mean value for pack–years smoked (TABLE 8). However, because pack–years of smoking may be confounded by age and years of exposure, we also examined the effect of smoking in a logistic regression analysis in which there were three categories of smokers: current, former, and never. The relative risk of current smokers was approximately two-fold greater than that of never-smokers for having asbestos-related disease. Surprisingly, former smokers did not appear to be at greater risk than never-smokers.

Because industrial hygiene data are not available to characterize the exposure of this cohort of asbestos-exposed workers, we can not directly examine whether a dose–response relationship applies to our radiographic findings. However, using the length of employment with the school district as a surrogate for duration of exposure to asbestos, we initially stratified the 422 participants without previous exposure across this variable and compared the prevalences of parenchymal as-

TABLE 7. Forced Vital Capacity (FVC) versus ILO Profusion Grade in 422 School District Employees, May 1983–June 1985

ILO Profusion Grade	Mean Percentage of Predicted FVC[a]
0/0	98.9
0/1	99.2
1/0	94.7
1/1	90.8
1/2	89.4
2/2	59.2

[a] Calculated by means of the regression equation of Morris *et al.*[7]

TABLE 8. Effect of Smoking on Radiographic Findings in 422 School District Employees, May 1983–June 1985

Cases	Mean Pack–Years
Parenchymal disease (n = 25)	28.6
Pleural disease only (n = 15)	12.3
Controls (n = 382)	11.0

TABLE 9. Effect of Length of Exposure on Radiographic Findings in 422 School District Employees, May 1983–June 1985

Length of Exposure	Rate of Parenchymal Cases (%)	Rate of Pleural Cases (%)
≤5 yr	1/51 (2.0)	1/51 (2.0)
6–10 yr	2/78 (2.6)	3/78 (3.9)
11–15 yr	4/81 (4.9)	2/81 (2.5)
>15 yr	18/212 (8.5)	14/212 (6.6)

TABLE 10. Arbitrary Exposure Categories in 422 School District Employees, May 1983–June 1985

Category	Number
Group 1: Plumbers	47
Group 2: HVAC/sheet-metal workers	47
Group 3: Other construction trades	154
Group 4: Custodial/building maintenance	102
Group 5: Miscellaneous	72

TABLE 11. Case Frequency versus Exposure Category in One School District

	Case Rate (%)	Mean No. of Pack–Years
Group 1: Plumbers	8/47 (17.0)	15.9
Group 2: HVAC/sheetmetal workers	3/47 (6.4)	6.7
Group 3: Other construction trades	16/154 (10.4)	9.8
Group 4: Custodial/building maintenance	9/102 (8.8)	11.7
Group 5: Miscellaneous	4/72 (5.6)	16.8

TABLE 12. Custodial/Building Maintenance Category in One School District

	No. of Cases (%)
Custodians (n = 30)	4 (13.3)
Plant managers (n = 32)	3 (9.4)
Building engineers (n = 40)	2 (5.0)
Total (n = 102)	9 (8.8)

bestosis and asbestos-related pleural disease (TABLE 9). The trend between increasing length of employment and higher prevalence of asbestos-related disease was confirmed by the logistic regression analysis in which the effects of age and smoking were adjusted. The relative risk of having asbestos-related disease was approximately 1.3 times greater for those participants with greater than 10 years of employment as compared to those who had just begun their employment.

To further evaluate the effect of exposure to asbestos among these school district employees, we arbitrarily categorized them into five different exposure groups (TABLE 10) in roughly descending order of intensity of exposure on the basis of the occupational histories reported by the employees. The prevalences of asbestos-related disease for these exposure categories are presented in TABLE 11. The only surprise was the relatively low prevalence of asbestos-related disease among HVAC (heating, ventilation and air-conditioning)/sheet-metal workers, but this may be due, at least in part, to less cigarette smoking in this group.

Finally, because considerable attention has been directed toward the risk of asbestos-related disease among school custodial/building maintenance workers, we present the number of cases from each of three school district job classifications which can be considered in this category of exposure (TABLE 12). Taken as a whole, the custodial/building maintenance employees surveyed had an approximately 9% prevalence of asbestos-related disease.

DISCUSSION

The results of this study indicate that long-term occupational exposure to asbestos-containing materials in public schools is capable of causing asbestos-related lung disease. More than 11 percent of workers known to have sustained exposure to ACM in school buildings, without history of exposure to asbestos prior to school district employment, and with at least 10 years of employment with the district had radiographic evidence of parenchymal asbestosis and/or asbestos-related pleural thickening. Although this study was descriptive in nature and no unexposed control group was available for comparison, the incidences of small, irregular opacities $\geq$ 1/0 by the ILO classification and bilateral pleural thickening observed for the participants clearly exceed those observed in the general population.[10,11] Although many of the school district employees participating in this study worked directly with ACM, a number of the participants were school custodians and building maintenance workers who were only indirectly exposed. The prevalence of asbestos-related disease among this latter category of workers was approximately 9 percent, suggesting that occupational exposure to asbestos dust generated by the deterioration of or damage to ACM in place was of considerable intensity in school buildings.

The reliability of our results rests on the quality of our radiographic data. All chest X-rays were taken by one of two California-licensed technicians using a single machine and a standard technique. Because a physician (usually one of us [J.B.]) was available to immediately review the films so that repeat views could be taken efficiently, good quality was readily maintained. The panel of B-readers utilized in the study included two chest radiologists who have been instructors in the national B-reading course sponsored by NIOSH and the American College of Radiology (E. Nicholas Sargent and J. Gordonson). The profusion scores used in the data analysis represented the mean of three independent ratings and at least two of the three readers had to agree that bilateral pleural thickening was present

for asbestos-related disease to be recorded. Furthermore, the inverse relationship observed between increasing ILO profusion score and mean percent of predicted FVC and FEV_1 provides evidence that the irregular opacities seen on the chest films actually do represent parenchymal fibrotic change. For these reasons, we believe that the radiographic findings in this study are reliable.

The participants with evidence of parenchymal asbestosis, but not those with asbestos-related pleural disease, smoked considerably more than did the other participants. This finding adds further support to the notion that cigarette smoking influences profusion scores in individuals with asbestos exposure, significantly increasing the likelihood that irregular opacities will be found on chest X-rays.[10] It is not likely that the irregular opacities were due to the effect of cigarette smoking alone since the decreased mean values for FEV_1 and FVC observed in cases of asbestos-related disease were not associated with significant airways obstruction (TABLE 6).

Although the data are limited because of the relatively small number of cases, the presence of decreased FEV_1 and FVC in association with asbestos-related pleural disease in our study is consistent with previous findings.[12]

The cross-sectional design of this study and the nature of the data collected (i.e., on respiratory morbidity rather than on mortality) do not allow us to address the important issue of the cancer risk of school custodial and building maintenance workers as a result of their exposure to ACM. Various estimates have been made of the excess deaths due to lung cancer and mesothelioma that will likely occur as a result of exposure of school children to airborne asbestos in classrooms.[13] However, because of the paucity of data concerning exposure to asbestos dust as a result of school custodial and building maintenance activities, no such estimates are available for workers who engaged in these activities. The risk of death attributable to exposure to asbestos in school buildings is undoubtedly higher for workers occupationally exposed than for school children environmentally exposed. Since relatively high doses of asbestos are required to produce radiographically apparent parenchymal and pleural fibrosis, the prevalence of asbestos-related lung disease that we report here suggests that the exposure of school custodial and building maintenance workers was considerable. Thus, the collection of mortality data for such workers should be a research priority.

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