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Mesothelioma Incidence and Community Asbestos Exposure

Michael Berry

Consumer and Environmental Health Services, New Jersey Department of Health and Senior Services, CN 360, Trenton, New Jersey 08625–0360

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This study evaluates the environmental, nonoccupational component of mesothelioma incidence among persons living in Manville, Somerset County, New Jersey, the location of the largest asbestos manufacturing plant in North America. Prior to removal of occupational cases, residents of Manville had an average annual (1979–1990) mesothelioma rate of 636 male cases and 96 female cases per million population, about 25 times higher than average state rates. Somerset County had 143 diagnosed mesothelioma cases reported to the population-based New Jersey State Cancer Registry from 1979 through 1990. Cases were removed from the analysis when their "usual employment" was reported as being at the asbestos plant, as evidenced through union lists or occupational information from either the Cancer Registry or mortality records. Standardized incidence ratios (SIRs) were computed for residents of Manville and Somerset County (less the Manville population) by sex. New Jersey mesothelioma rates less the Somerset County contribution, 1979–1990, were used to generate the expected number of cases. The SIRs for Manville males and females were respectively 10.1 [95% confidence interval (CI): 5.8–16.4] and 22.4 (95% CI: 9.7–44.2). Male and female Somerset County mesothelioma incidence rates were 1.9 (95% CI: 1.4–2.5) and 2.0 (95% CI: 1.0–3.6). This record-based approach demonstrates a strong relationship between past asbestos exposure from living in Manville and eventual development of mesothelioma. The use of methods in this study may be helpful in evaluating hazards of other known occupational carcinogens found in community settings.

INTRODUCTION

Mesothelioma is a rare type of cancer. The National Cancer Institute's (NCI's) Surveillance, Epidemiology, and End Results (SEER) Program estimates that mesothelioma occurs nationally at an annual rate of 14 cases per million population for males and 3 cases per million population for females (NCI, 1987). Mesothelioma incidence in New Jersey is higher than SEER estimates and not uniformly distributed throughout the state's 21 counties. Somerset County, New Jersey, has long been considered an area that had unusually high mesothelioma rates in the state.

New Jersey has traditionally been the center of operations for many asbestos products manufacturers and shipyards (Stanbury and Rosenman, 1987). Between 1912 and 1980, Manville, located in Somerset County, was the site of the largest asbestos products manufacturing plant in North America. The plant employed up to 3500 people at one time and manufactured asbestos products for more than 70 years.

In 1987, NJDOH conducted a death certificate analysis of mesothelioma and residence in Somerset County (Miller *et al.*, 1988). That study was designed to evaluate the cancer mortality risk after removing the effect of employment at the asbestos plant through the use of a union employment list. Miller *et al.* (1988) detected a significantly elevated odds ratio of 4.4 ($P < 0.02$) for living in Manville. The small number of cases and possible coding errors on death certificates of mesothelioma to other cancer types in this earlier study suggested follow-up of these observations. The purpose of the present study was to evaluate the environmental (nonoccupational) component of the incidence of this rare cancer, using a population-based registry, among persons living in an area that had an asbestos manufacturing plant with potentially significant population exposures.

METHODS

The study area for the mesothelioma investigation included the total area and population of Somerset

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County, New Jersey. Manville, in Somerset County, was considered the focal point of highest environmental exposure to ambient asbestos fibers due to the operation of a large asbestos manufacturing plant (see Fig. 1). For purposes of this study, the population living in Manville at the time of cancer diagnosis was designated the "exposed" population. The relatively "lower exposed" population was defined as those persons living in Somerset County but not in Manville at the time of cancer diagnosis. For comparison purposes, the "unexposed" population was defined as the entire state of New Jersey minus Somerset County.

The period of interest in this study was 1979 through 1990, a 12-year study period. This study period was chosen because (1) a sufficient period (at least 60 years) had elapsed from earliest possible ambient exposures from the plant to the expression of mesothelioma in the community (to account for the latency of the disease), and (2) the New Jersey State Cancer Registry had complete records for the study period.

For the purpose of calculating population statistics, the 1980 and 1990 U.S. Census Bureau population data were averaged. Population averages were calculated for 18 five-year age groups, providing the most representative estimate of the size and age structure of the study population.

The New Jersey State Cancer Registry was used for the ascertainment of cases. The Cancer Registry, operated by the New Jersey Department of Health, is a population-based cancer incidence registry covering the entire state of New Jersey. By law, specific data on all individuals residing within New Jersey who have newly diagnosed cancers must be reported to the Registry. In addition, the Registry has reporting agreements with neighboring states (Delaware, New York, and Pennsylvania), where information on

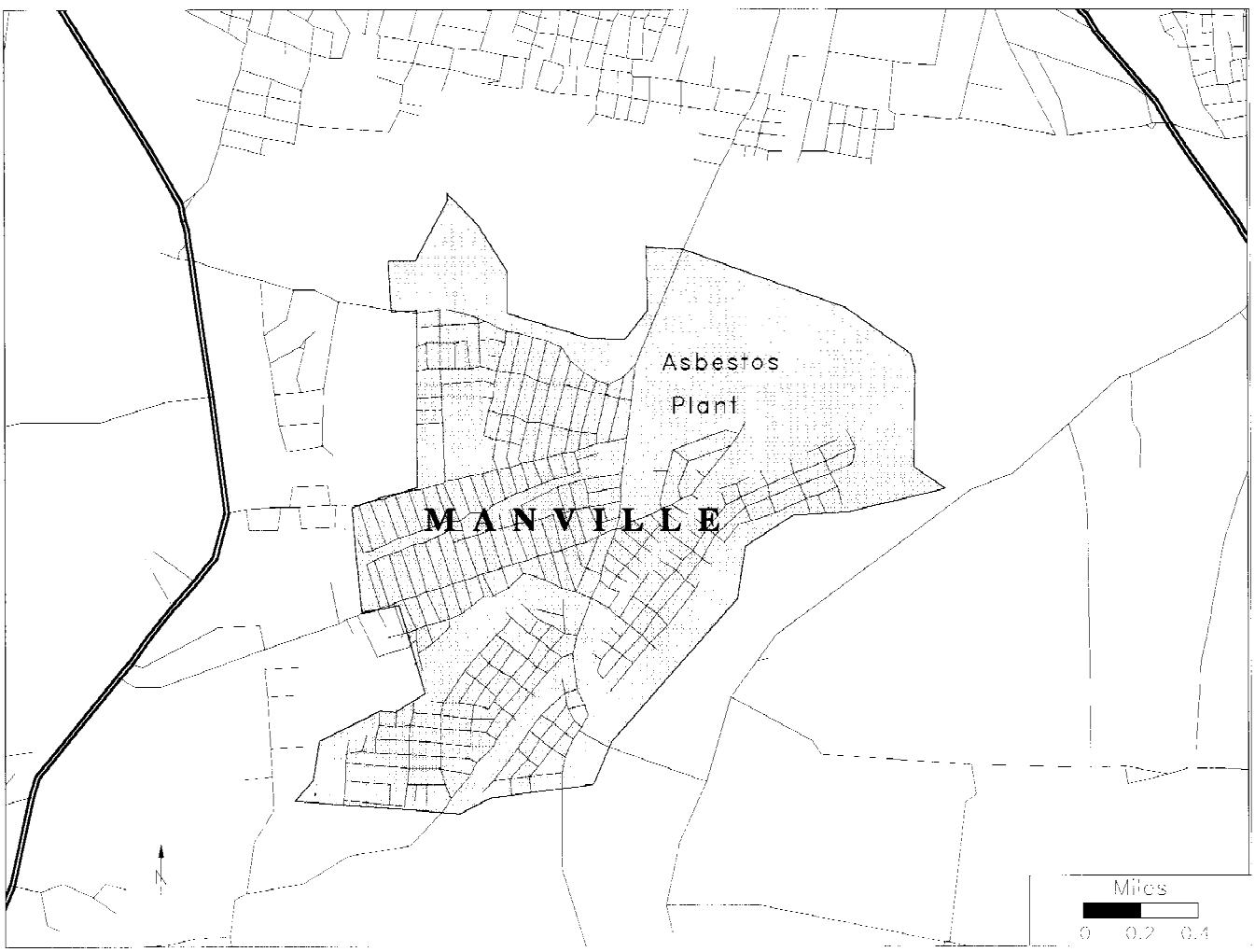

FIG. 1. Location of the asbestos manufacturing plant in Manville, New Jersey.

New Jersey residents who are diagnosed in those states will be supplied to the New Jersey Cancer Registry.

A case was defined as a new primary incident mesothelioma cancer (ICD-O histology code: 9050–9053) diagnosed in a New Jersey resident between January 1, 1979, through December 31, 1990. The histology code is defined by the tissue type of the neoplasm and includes both pleural and peritoneal mesotheliomas.

Information for each newly diagnosed cancer available from the Cancer Registry was limited to the Cancer Registry abstract of information from the patient medical record. The collected information included demographic data on each patient and medical data on each cancer. Variables used to analyze the incidence of cancer in the county included name, address at time of diagnosis, county and municipality codes, occupation and industry codes, date of diagnosis, primary cancer site, histology type, age at diagnosis, date of birth, race, sex, and Registry identification number.

Information on other risk factors such as the extent of occupational exposure or personal lifestyle habits was unknown for the study population. No personal interviews or other means of data collection for these factors were feasible for this project.

To better evaluate the impact of environmental exposure to asbestos, Somerset County mesothelioma cases who were identified through one of three sources as having worked at the asbestos plant in Manville were removed prior to analysis. The three data sources used to determine the occupations of the cases were Cancer Registry records, death certificates, and a list of all members of the single union representing employees at the plant. The Cancer Registry and death certificates provided information on the usual occupation, type of business or industry, and name and address of employer. The union list comprised all unionized employees at the asbestos plant who started working between October 1912 and December 1958, approximately 20 years prior to the beginning of the study period. Virtually all production employees during this period were members of the union, including those hired for shirt-term and summer employment. Salaried employees were not eligible for union membership and represent a fraction of the entire workforce.

Direct standardized average annual mesothelioma incidence rates, adjusted to the 1970 U.S. standard population, were calculated for New Jersey, Somerset County, and Manville prior to removing the occupational cases. Indirect standardized incidence ratios (SIRs) were then calculated for mesothelioma both for Manville and for all of Somerset County exclusive of Manville after removal of asbestos plant employees. The SIR was calculated by dividing the observed number of cases by the expected number of cases. The expected number was derived by multiplying the state modified average annual age- and sex-specific mesothelioma incidence rates, 1979–1990, with the study area, age- and sex-specific population averages from the 1980 and 1990 census data. The modified state mesothelioma rates were calculated by subtracting the Somerset County population and cases from the state figures. The 95% confidence intervals (CIs) of the SIRs were calculated to assess statistical significance using the estimation method of Byar (Breslow and Day, 1985).

RESULTS

The population average (1980 and 1990) for Somerset County was 208, 435 (102,344 males or 49.1% of the total) and represents about 2.8% of the total state population. Manville's average population represented 5.2% of the county and was 10,923 (5,310 males or 48.6%). The median age for Manville, Somerset County, and New Jersey residents was similar for both males and females (32 and 34 years of age, respectively). The percentage of the population aged 65 and over varied slightly between Manville, Somerset County, and the state (males were 10.3, 8.0, and 10.3% and females were 13.9, 11.0, and 14.3%, respectively). Manville and Somerset County had a greater percentage of white residents compared with the state (99, 93, and 81%, respectively).

A total of 1358 newly diagnosed mesothelioma cases (1111 males and 247 females) were reported to the New Jersey State Cancer Registry over the 12-year study period for the entire state. Of this total, 143 mesothelioma cases (122 males, 21 females) were identified as residents of Somerset County and 55 (46 males, 9 females) of those were residents of Manville.

Table 1 lists the average annual standardized mesothelioma incidence rates for New Jersey, Somerset County, and Manville prior to removal of plant employees. New Jersey's mesothelioma rate was slightly higher than SEER estimates: 25 male cases per million population and 4 female cases per million population. The mesothelioma rate for Somerset County was approximately four times higher (103 per million males and 14 per million females) than the average state rate. The Manville mesothelioma rate was substantially higher than that of the state with 636 male cases per million population and 96 female cases per million population.

TABLE 1

Average Annual Adjusted[a] Mesothelioma Incidence Rates (1979–1990) per Million Population for Manville, Somerset County, and New Jersey prior to Removal of Plant Employees

Population	Sex	Mesothelioma		
		Number of cases	Incidence rate (per million)	Ratio to state
Manville	Male	46	635.6	25.8
	Female	9	95.9	23.2
Somerset County	Male	122	102.6	4.2
	Female	21	13.8	3.3
New Jersey	Male	1,111	24.7	
	Female	247	4.1	

[a] Rates standardized to the 1970 U.S. population.

Of the 143 incident mesothelioma cases in Somerset County, a total of 61 cases were identified as persons having worked at the Manville plant (Table 2). The breakdown for method of identification was 55 by death certificates (55/61 or 90.2%), 41 by the union list (41/61 or 67.2%), and 30 by the Cancer Registry (30/61 or 49.2%). (The methods were not mutually exclusive.) Death certificates were located for 135 (94.4%) of the mesothelioma cases. Of the 61 identified as having had previous employment at the plant, 31 were residents of Manville at the time of diagnosis and the other 30 resided elsewhere in the county.

A total of 82 cases (63 males, 19 females) had no evidence of employment at the plant in any of the available data sources. For mesothelioma cases without evidence of employment at the plant, 24 were residents of Manville and 58 resided elsewhere in the county. These 82 cases were used for the following analyses.

TABLE 2

Mesothelioma Incidence (1979–1990) for Somerset County, New Jersey, and Employment History at the Manville Asbestos Plant

Identified employment at JM Corp.	Source of employment data[a]	Mesothelioma cases		
		Male[b]	Female	Total
Yes	DC, UL, and CR	19		19
	DC and UL	17		17
	DC and CR	9	1	10
	DC only	8	1	9
	UL only	5 (1)		5
	CR only	1 (1)		1
	Total yes	59 (2)	2	61
No evidence		63 (6)	19	82
Total		122 (8)	21	143

[a] Source of employment data: DC, death certificate; UL, union list; CR, Cancer Registry.

[b] Parenthetical numbers are cases without death certificates.

Table 3 lists the results of the SIR analysis. Mesothelioma incidence in Manville residents who did not work at the plant was significantly elevated for males, females, and the total population relative to average state rates. Manville females had the highest SIR for mesothelioma, 22.4 (95% CI: 9.7–44.2). The mesothelioma SIR for Manville males was 10.1 (95% CI: 5.8–16.4).

The SIR analysis for the rest of Somerset County detected significantly elevated rates for both males and females. However, the difference between the observed and expected numbers was much smaller than for the Manville SIRs: the female Somerset County SIR was 2.0 (95% CI: 1.0–3.6) and the male Somerset County SIR was 1.9 (95% CI: 1.4–2.5).

DISCUSSION

The purpose of this study was to evaluate the environmental, nonoccupational component of mesothelioma in an area that had a long-term asbestos manufacturing operation. These data indicate that residents of Manville had an extremely elevated risk of developing mesothelioma relative to average state incidence rates. A strength of this study is that a union employee list and two independent registry sources were used to evaluate occupation to minimize the potential effect of misclassification of occupation by any one source, leaving a more accurate assessment of the environmental impact on the community. However, since full occupational histories were not collected for the mesothelioma cases, it is possible that some of the cases may have worked at the Manville facility sometime during their life. The impact of this type of misclassification of employment would be to overestimate the environmental component in the analysis.

Asbestos exposure had been suspected as a risk factor for mesothelioma since 1943 (NCI, 1987), but not until 1960 did a study of asbestos miners and neighborhood residents in South Africa (Wagner *et al.*, 1960) firmly establish an association. Numerous occupational studies have documented increased risks among workers in asbestos mines and factories, installation, shipbuilding, and other occupations involving inhalation of asbestos dust (IARC, 1977; McDonald and McDonald, 1978; Newhouse, 1977; Selikoff, 1977; Selikoff and Hammond, 1979; Tagnon *et al.*, 1980).

The South African report (Wagner *et al.*, 1960) noted that one-third of the mesothelioma cases had no employment history associated with asbestos.

TABLE 3

Mesothelioma Standardized Incidence Ratios (1979–1990) for Manville and Somerset County, New Jersey, after Removal of Plant Employees

Population	Sex	Mesothelioma cases			95% CI
		Observed	Expected	SIR	(lower–upper)
Manville	Male	16	1.6	10.1*	5.8–16.4
	Female	8	0.4	22.4*	9.7–44.2
Somerset County except Manville					
	Male	47	25.1	1.9*	1.4–2.5
	Female	11	5.5	2.0*	1.0–3.6

* Statistically elevated, $P < 0.05$.

These nonoccupational cases were exposed to asbestos because they lived near asbestos mines and mills. Three European studies (Newhouse and Thompson, 1965; Hain *et al.*, 1974; Magnani *et al.*, 1995) detected excess cases in the immediate neighborhood of factories that processed asbestos, mainly from the same South African mines (McDonald, 1985). Household contacts of asbestos workers were also at elevated risk for asbestos-induced diseases including mesothelioma (Newhouse and Thompson, 1965; McDonald and McDonald, 1980; Anderson *et al.*, 1979; Vianna and Polan, 1978).

Although the larger, heavier asbestos particles settle to earth relatively quickly with limited potential for environmental (off-site) contamination, an appreciable fraction of the asbestos discharged by asbestos facilities has been documented to be in the form of free fibers that could potentially remain in the atmosphere for long periods, travel great distances, and expose many people (Laamanen *et al.*, 1964). Laamanen's studies of atmospheric population in the area surrounding asbestos mines and mills in Finland showed small amounts of asbestos dust as far away as 27 km.

The two major routes of environmental exposure for the current study were considered to be ambient air and household contact with plant employees. Based on anecdotal information from residents and plant employees, the asbestos manufacturing operation in Manville produced large quantities of particles that were released on a daily basis from stacks directly into the ambient air (Borow and Livornese, 1973). These fugitive emissions regularly coated cars, homes, and yards like a fresh snowfall in much of the immediate community. Asbestos contamination of the community over the decades of operation could persist due to the stability of the fibers. Hammond *et al.* (1979) reported that dust samples collected from houses located near an asbestos factory contained appreciable amounts of asbestos fiber even many years after the factory closed.

The asbestos plant in Manville produced multiple products primarily using chrysotile asbestos (approximately 95%). A gradual reduction of asbestos use began in the early 1970s with an abrupt shift to substitute materials or elimination of product line in 1980. There is some information suggesting that chrysotile fibers are not as hazardous as other types of asbestos, especially crocidolite (NCI, 1981). An important distinction between this study and other affected neighborhood studies (Wagner *et al.*, 1960; Newhouse and Thompson, 1965; Hain *et al.*, 1974; McDonald, 1985) is the type of asbestos fibers contaminating the environment. Although crocidolite was the major form of asbestos in the earlier studies, this study suggests a major community impact by a facility using primarily chrysotile fibers.

After removal of cases with known employment by the plant, mesothelioma incidence rates in Somerset County were found to be substantially elevated during the 1980s relative to state and national rates. Incidence in Somerset County exclusive of Manville remained statistically elevated and about double the average state rates. Manville mesothelioma rates compared with average state rates were found to be extremely elevated, 10 to 20 times greater than expected. Possible explanations for the elevated county mesothelioma incidence include a carry-home effect due to plant employees living outside of Manville, outmigration of Manville residents to other locations within the county prior to their diagnosis, and employment misclassification.

A limitation of this study was the inability to distinguish between cases attributable to ambient airborne contamination and those attributable to household contact with an asbestos worker. However, it has been estimated that neighborhood asbestos exposure and family contact are roughly equal in their community impact (Newhouse and Thompson, 1965).

Most of the potential sources of bias in the study design tend to underestimate the measure of effect

(bias toward the null hypothesis of no effect). Since mesothelioma cases among the plant workers were excluded, all plant workers living in the county should theoretically be removed from the population estimates (census data) for Manville and Somerset County. However, this was impossible to accomplish since information on the residence of former employees was not readily available. The consequence of not removing the plant employees from the census numbers would be to underestimate the magnitude of the effect, especially for Manville, since the facility was the major employer in the town and likely employed many of its residents. Additionally, recent inmigration of unexposed people and/or outmigration of mesothelioma cases prior to diagnosis would also bias the SIRs for Manville toward the null.

Another potential problem is the possible miscoding or absence of occupational information in the vital statistics records used in this study. Although 61 of 143 Somerset County mesothelioma cases were identified as having worked at the Manville plant, the lack of definitive evidence of employment obtained through occupational histories for the other 82 cases could lead to false negatives. Since no interviews were conducted to verify occupational history, some of the cases included in the analysis may have worked at the Manville plant. Similarly, Somerset County mesothelioma cases could have had a history of previous residence in Manville.

For decades, the asbestos facility in Manville was the predominant employer in the town. Little other industry existed within Manville. Other industrial facilities did exist in other Somerset County communities, and in nearby counties, representing possible occupational sources of exposure for residents of Manville. However, New Jersey has long been a highly industrialized state with numerous such facilities within its borders. With the exception of working at the Manville asbestos plant, the premise of this study was that the likelihood of employment in other high-risk occupations or facilities would not differ from that of the state as a whole, which was used as the comparison population.

This study used incidence data from a population-based Cancer Registry for case ascertainment instead of death certificates because of the greater sensitivity of detecting mesothelioma cases (Ducic, 1971; McDonald, 1979; Newhouse and Wagner, 1969). However, once incident case reports were generated from the Registry, collection of a death certificate for each case proved to be a better way to identify previous employment at the plant compared with the union list or the Cancer Registry (90% versus 67 and 49%, respectively).

The relationship between asbestos and mesothelioma is unusual in the epidemiology of diseases caused by environmental factors in that, other than asbestos, there are no other known or suspected causes for this rare cancer (NCI, 1987). Asbestos exposure appears to be necessary for the development of mesothelioma; i.e., there is specificity of exposure for this effect. Such specificity is not found for most other environmental exposures demonstrated to cause diseases. Nevertheless, this study does have implications for other environmental toxics which may not be the only cause of the diseases for which they are associated. Asbestos is the prime example of a substance for which the detrimental effects have been demonstrated almost exclusively in the occupational arena. Many exposures shown to be toxic in the occupational setting are presumed to pose similar kinds of hazards at lower levels in the environment. While such presumptions are good public health practice, demonstration of consistency of effect and dose response is extremely useful for indicating that preventive actions in the community are well grounded. This study can serve to strengthen the public health underpinning of activities already in place that serve to prevent community exposure to asbestos.

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