Cancer Incidence Following Exposure to Drinking Water with Asbestos Leachate

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Synopsis

In November 1985, the New York State Department of Health was alerted to extraordinary concentrations of asbestos leachate in the drinking water in the Town of Woodstock. Concentrations of 3.2 million fibers per liter (MFL) to 304.5 MFL were found, depending on location. An investigation of cancer incidence in the area was conducted for the period 1973–83 using the State Cancer Registry to compute standardized incidence ratios.

No evidence was found of elevated cancer incidence at sites associated with asbestos exposure. A statistically non-significant excess of kidney cancer was seen among men, but not women. Colon cancer among men was significantly low, but incidence among women was similar to that expected. Lung cancer incidence was lower than expected for both sexes. Ovarian cancer rates were not different from expected rates. At sites not previously related to asbestos exposure, cancer of the oral cavity was significantly high, with most affected persons having a history of cigarette smoking. Surveillance of the community is continuing because of an insufficient latent period for some exposed groups.

THE CARCINOGENIC EFFECTS of asbestos exposure are associated with serious and fatal illness. Most studies have examined disease risk among persons occupationally exposed to air-borne asbestos fibers (*1–4*). The risks associated with asbestos in drinking water supplies have been of growing concern since high concentrations of asbestos were found in Duluth, MN (*5*). Since occupational exposure to asbestos is related to increased risk of cancer of the gastrointestinal tract, long-term ingestion of the fibers may increase risk (*3*). Waterborne asbestos exposure has been studied at different locations (*6–11*).

Many communities are expressing concern about ingested asbestos exposure as a result of the use of asbestos-cement (A/C) pipe in public water systems (*9–11*). Research in such communities has defined exposure as the presence of asbestos-cement pipe. In some cases, the question of the corrosiveness of water as a necessary condition for A/C pipe deterioration has not been addressed (*9, 11*).

In November 1985, the New York State Department of Health was alerted to a problem of extraordinary concentrations of asbestos leachate in the public drinking water supply in the Town of Woodstock, located in the mid-Hudson River valley of the State. In response, the Department initiated

- Measurements of airborne asbestos in a sample of homes in the area ("Asbestos-contaminated water: its impact on indoor residential air," unpublished report, New York State Department of Health, J. S. Webber, S. Syrotynski, and M. V. King, 1985);
- An investigation of cancer incidence in the area using data from the New York State Cancer Registry as a first step to try to determine whether asbestos exposure had had a large impact on health (the availability of registry data enabled the Department to respond quickly to public concerns about cancer risk);
- A community registry of exposure individuals to provide the basis for long-term surveillance; and
- Immediate remedial action to replace the deteriorating A/C pipe.

Our report describes the cancer incidence investigation as a demonstration of how a public agency can respond to public concern using epidemiologic

Table 1. Asbestos levels found in drinking water at various locations in Town of Woodstock, NY, 1985 (million fibers per liter)

Sample	All fibers	Fibers greater than 10 microns
1	304.5	9.9
2	116.9	15.1
3	78.3	7.5
4	19.4	0.9
5	3.2	1.2

SOURCE: New York State Department of Health, Bureau of Public Water Supply.

methods and available data to provide information on the health status of an exposed community.

Background

Several areas of Woodstock were developed for housing in the mid-1950s. At that time asbestos-cement pipe was used to connect homes to the public water supply. In the fall of 1985, a water contamination problem was identified after the water supply had been turned off for service and repairs. Numerous complaints regarding low water pressure led to the discovery of filters clogged with a fibrous substance, later identified as asbestos. Five water samples taken from residences after extensive flushing of the system were analyzed. The results are summarized in table 1. The concentrations of asbestos, expressed in millions of fibers per liter (MFL), ranged from 3.2 MFL to 304.5 MFL. Chrysotile and crocidolite forms of asbestos were present. Long fibers, those longer than 10 microns in length, were found in concentrations ranging from 0.9 MFL to 15.1 MFL.

The duration of exposure could not be determined. One housing development had received public water through asbestos-cement pipe since its construction in the mid-1950s. The addition of a new pump house to the water system in the mid-1960s resulted in all drinking water being routed through A/C pipes, potentially exposing everyone drinking public water. Serendipitous evidence dated the presence of asbestos in the system from at least 1976. This was determined from analysis of a jug of water left from a 1976 camping trip and saved since then in a garage.

The water in the Woodstock system is soft, has a low pH (is acidic), and is highly corrosive, measuring −3.1 on the Langelier Index (an indication of the aggressiveness of water). The asbestos exposure in the Woodstock system (an average of 104.5 MFL) was higher than that determined in any other study except that of Puget Sound. The volume of asbestiform fibers found in other studies ranged from 0.5 MFL in the Connecticut study to 206 MFL in the Puget Sound study. In Florida study areas, fiber volume ranged up to 10.7 MFL, and up to 36 MFL in San Francisco. Duluth was the only study in which amphibole-type asbestos fibers were found. While the volume of fiber was low in Connecticut, the size of fibers was longer, with 11 percent longer than 10 microns (*12*). In the Puget Sound study, 90 percent of fibers were less than 5 microns in length. Fiber size, length, and fibertype (amphibole versus chrysotile) are key factors in assessing risk from asbestos exposure (*13*). One to 15 percent of fibers in Woodstock water were longer than 10 microns. Many published studies have not addressed all size issues.

Asbestos is a human carcinogen. In studies of animals, ingested fibers varying in length and width have been found in organs such as the gastrointestinal tract, kidney, spleen, and liver (*14–15*). In studies of humans, a positive association between asbestos and cancer risk has been shown in occupational settings. However, the lack of positive findings in studies designed to detect the effects of ingested waterborne fibers may result from an inability to detect the health effects of environmental exposure.

Etiological links in environmental health studies are difficult to demonstrate when

- Exposures are at low levels and short durations;
- Migration in the study population increases the likelihood of misclassification of exposure;
- The diseases being considered usually have low rates of incidence;
- The expected increases in disease are low; and
- The period between exposure and onset of disease is long.

The Environmental Protection Agency's assessment of risk for ingested asbestos indicates that a lifetime exposure (70 years) to 0.3 MFL will increase the number of cancer cases by 1×10^{-5} per year (*16*). Extrapolating this risk assessment to exposure levels found in Woodstock, the estimate of the maximum excess cancer per year would range from 10×10^{-5} to 10×10^{-3}.

Methods and Materials

The study area was defined as the smallest area which would include the entire water district in the Town of Woodstock and for which population

data by age and sex were available from the 1980 Census. (The census definition for the area included block group (BG) 5 of block numbering area (BNA) 9904, BG 1 and 2 of BNA 9906, and BG 1 of BNA 9907. The four block groups made up the study area. A map of the study area is available from the author.)

The study period 1973–83 was chosen because the mid-1970s is the earliest period that an effect from asbestos exposure might be seen, consistent with a 20- to 30-year latency period between asbestos exposure and clinical onset of disease. The year 1983 was selected as the most recent year that reporting to the New York State Cancer Registry was considered complete enough for small area analysis at the time the study was conducted.

All cases of cancer diagnosed among residents of the study area during the years under investigation were identified through the Cancer Registry. The registry contains information on all cases of cancer reported by hospitals and physicians to the New York State Department of Health, as required by law. An estimated 95 percent of cancer cases are reported (*17*).

The address for each case was examined to determine whether the person lived within the boundaries of the study area at the time of diagnosis. The cases were grouped by tumor site, sex, and age. The expected numbers of cancer cases were calculated by applying age-, sex-, and site-specific cancer incidence rates for New York State, excluding New York City, for the period 1978–82 to the study population. According to the 1980 U.S. Census, the collective population of the study was 2,679, which included 1,235 men and 1,444 women. Standardized incidence ratios were calculated for 17 of the most common cancer sites among men and 19 among women.

The Poisson model was used to assess the probability that chance alone could explain a given increase or decrease in the observed number of cancer cases or deaths relative to the expected number (*18*). If the probability was 0.05 or less for any cancer site, it was considered to be a statistically significant excess or deficit, using a two-tailed test. Standardized incidence ratios (SIR), with 95 percent confidence intervals (CI) were calculated, using Bailar and Ederer's method for Poisson variables (*19*).

Airborne asbestos exposure has been linked in epidemiologic studies to cancers of the gastrointestinal system, lung, and mesotheliomas of the lung and abdominal cavity (*3, 20*). Kidney cancer has been noted among men working with insulation products containing asbestos (*20*). Although most investigations have been limited to men, those that have included women workers have noted an excess of ovarian cancer (*21, 22*). Research on ingested asbestos has not yielded consistent results, but has focused on gastrointestinal cancers.

Table 2. Standardized incidence ratios (SIR) [1] and 95 percent confidence intervals (CI) for cancer cases by site and sex in the study area, Town of Woodstock, NY, 1973–83

Site [2]	Males		Females	
	SIR	95 percent CI	SIR	95 percent CI
Buccal (140–149)	3.0	1.2, 6.1	0.0	0.0, 3.0
Stomach (151)	0.0	0.0, 1.7	0.0	0.0, 2.5
Colon (153)	0.1	0.0, 0.7	1.1	0.5, 2.0
Rectum (154)	0.8	0.2, 2.4	1.3	0.4, 3.4
Liver (155)	0.0	0.0, 6.4	0.0	0.0, 9.5
Pancreas (157)	1.4	0.3, 4.1	2.0	0.5, 5.0
Lung (162)	0.4	0.2, 0.9	0.5	0.1, 1.4
Melanoma (172)	1.7	0.2, 6.0	0.9	0.0, 4.7
Breast (174)	...		1.4	0.9, 2.0
Uterus (179, 182)	...		0.7	0.1, 1.9
Cervix (180)	...		2.2	0.6, 5.5
Ovary (183)	...		1.0	0.2, 2.9
Prostate (185)	1.7	1.0, 2.6	...	
Testis (186)	1.6	0.0, 9.1	...	
Bladder (188)	0.9	0.3, 2.1	0.5	0.0, 2.9
Kidney (189)	3.0	1.0, 6.9	0.0	0.0, 3.4
Brain (191)	0.0	0.0, 3.7	2.3	0.3, 8.4
Thyroid (193)	0.0	0.0, 12.7	1.3	0.0, 7.3
Lymphoma (200–202)	0.8	0.1, 2.8	2.0	0.7, 4.7
Leukemia (204–208)	0.9	0.1, 3.4	0.6	0.0, 3.3
All other	0.3	0.0, 0.9	0.6	0.2, 1.5
All sites (140–208)	0.9	0.7, 1.1	1.0	0.8, 1.3

[1] Ratios adjusted for age and sex in an upstate New York population.
[2] Site classification according to International Classification of Diseases, 9th revision.
SOURCE: New York State Cancer Registry, Bureau of Cancer Epidemiology, New York State Department of Health, January 1986.

Results

The total number of cancer cases observed in the study area was 127, with a SIR of 0.9 (95 percent CI = 0.8, 1.1). The standardized incidence ratios by site and sex are summarized in table 2. To help interpret these ratios, table 3 provides the observed and expected numbers of cases by sex and site. The numbers of cases were grouped for some sites to protect the privacy of individuals.

Cancer incidence was not elevated in sites which have been related to asbestos exposure in previous studies, when compared with the expected figures for upstate New York. Despite the high concentrations of asbestos in the drinking water, no evidence was found for elevated cancer risk at any sites previously associated with asbestos exposure. Although not shown in the tables, no mesotheliomas

Table 3. Observed and expected numbers of cancer cases by site and sex for the study area, Town of Woodstock, NY, 1973–83

Site [1]	Males		Females	
	Observed [2]	Expected [3,4]	Observed [2]	Expected [3,4]
All sites (140–208)	59	67.6	70	66.7
Oral (140–149)	7	2.4	0	1.2
Gastrointestinal (151–155, 157)	7	16.3	18	15.5
Lung (162)	7	14.4	([5])	6.2
Breast (174)	...	...	24	17.6
Female reproductive (uterus, cervix, ovary) (179, 180, 182, 183)	...	...	10	9.4
Prostate (185)	19	11.5	...	...
Urinary tract (bladder, kidney) (188, 189)	10	7.2	([5])	3.0
Other [6]	9	15.3	18	23.0

[1] Site classification according to International Classification of Diseases, 9th revision.
[2] New York State Cancer Registry, Bureau of Cancer Epidemiology, New York State Department of Health, as of January 1986.
[3] Expected number derived by applying age, sex, and population density-specific rates for New York State, excluding New York City, to the 1980 population of the study area.
[4] Expected numbers may not add to total because of rounding.
[5] Observed number is less than 6, and was included in the "other" category. Expected values are shown, but also are included in the "other" category.
[6] Includes, among others, melanoma (172), female urinary tract (188, 189), female lung (162), brain (191), thyroid (193), leukemia (204–208), and lymphoma (200–202).

(ICD-9, morphology of neoplasms, M905) were detected. A nonsignificant excess of kidney cancer was seen in men but not in women. Cancer of the colon among men was significantly low, but incidence was similar to that expected among women. The number of lung cancer cases was lower than expected for both men and women. The incidence of cancer of the ovary was not different from the expected incidence.

For cancer sites not previously related to asbestos exposure, cancer of the oral cavity was significantly high in men, with the majority having a history of cigarette smoking.

Discussion

The ecological design is a limitation of the study, as it is for most studies of ingested asbestos. Asbestos exposure is defined by geographic location of residence at the time of cancer diagnosis. Such data cannot be used to support an etiologic relationship between the exposure and observed cancer incidence. The purpose of the cancer incidence study, however, was not to establish an etiologic link, but rather to respond quickly to the community's concern about its exposure, and its need for information about potential carcinogenic effects. The data were used to define the magnitude of the public health impact and to plan appropriate long-term surveillance protocols.

The study design could cause misclassification of exposure, either as the result of population migration, or the lack of individual historical exposure data. Exposed persons who migrated out of the area prior to a diagnosis of cancer could not be included. Since block groups were not defined for the area in the 1970 Census, and since Woodstock did not become a Census Designated Place until the 1980 Census, no comparable data were available to assess migration, population, or housing starts during the study period.

In Woodstock, many of the residents within the study area were not on the public water supply. A study only of those persons supplied from the public water supply could not be done because census data describing the water district by age and sex were not available for this investigation. In addition, about half of the households within the water district were not connected to the public water supply. Individuals in those households could not be identified by either the current or historical billing records of the town's water department.

A major scientific issue in cancer epidemiology is the latency between exposure and the onset of clinically recognizable disease. Based on evidence from the Bureau of Public Water Supply of the New York State Department of Health, residents of the housing development in BG 2 of BNA 9906 potentially were exposed to drinking water containing asbestos leachate beginning in the mid-1950s, and the remainder of the study area residents on public water from the mid-1960s, assuming that the pipes began to deteriorate immediately. Thus, at least a 10-year latency existed before the study period began for all those who were residents during that time. A potential 20-year latency was evident for the long-term residents of the housing development with the highest concentrations of asbestos, with some residents having up to 30 years of potential exposure. However, not all of the

residents could have experienced the maximum latency of 30 years from the beginning of potential exposure.

In drawing conclusions from the data, two aspects of the statistical method need to be addressed. First is the problem of multiple hypothesis testing, whereby a high probability exists for results to appear to be statistically significant despite differences between the observed and expected numbers resulting entirely from random fluctuations in the data. The excess of oral cancer among men and deficits in lung and colon cancer among men could be chance findings.

The second aspect is the power of the statistical test. In the study area, the power of detecting a 50 percent increase in the true incidence rate was low for each sex-specific site. However, there was more than an 85 percent probability that the increase could be detected if all sites previously associated with asbestos were combined. These would include lung, gastrointestinal, kidney, and ovarian cancers.

The general pattern of cancer incidence reported to the New York State Cancer Registry shows that in men, lung, colon, and prostate cancers are the most commonly reported sites. In women, the most commonly reported cancer sites are breast, lung, and colon. In the study area, while breast and prostate cancers were observed most frequently, cancers of the lung and colon in both sexes had a relatively low incidence. If these results were not from chance, they suggest that risk factors, other than asbestos exposure which has been associated with the cancer sites, may be different for the population in the study area than for the upstate New York population in general.

Several unusual characteristics of the study area population were evident, as described in data from the 1980 Census. Nearly 60 percent of the residents 25 years and older had some college education, and 41 percent were college graduates. Forty-nine percent were employed in managerial and professional occupations, and 33 percent in professional specialities. However, the median income for households in the study area was $14,546, a low level for a community with such a high proportion of adult residents with a college education. The characteristics point to an area which may have an unusual mix of lifestyles, compared to other areas of New York State, excluding New York City.

Conclusion

The New York State Department of Health is continuing its surveillance of the community. A registry of all exposed residents has been developed to monitor the incidence of untoward health effects associated with asbestos exposure. The followup will continue to diminish the probability that the negative findings of the cancer investigation are the result of insufficient latency among those exposed.

References

1. Newhouse, M. L., and Berry, G.: Patterns of mortality in asbestos factory workers in London. Ann NY Acad Sci 330: 53–60 (1979).
2. Seidman, H., Selikoff, I. J., and Hammond, E. C.: Short-term asbestos work exposure and long-term observation. Ann NY Acad Sci 330: 61–89 (1979).
3. Selikoff, I. J., Hammond, E. C., and Seidman, H.: Mortality experience of insulation workers in the United States and Canada, 1943–1976. Ann NY Acad Sci 330: 91–116 (1979).
4. Henderson, V. L., and Enterline, P. E.: Asbestos exposure: factors associated with excess cancer and respiratory disease mortality. Ann NY Acad Sci 330: 117–126 (1979).
5. Nicholson, W. J.: Analyses of amphibole fibers in municipal water supplies. Environ Health Perspec 9: 165–172 (1974).
6. Polissar, L., Severson, R. K., Boatman, E. S., and Thomas, D. B.: Cancer incidence in relation to asbestos in drinking water in the Puget Sound region. Am J Epidemiol 116: 314–328 (1982).
7. Wigle, D. T.: Cancer mortality in relation to asbestos in municipal water supplies. Arch Environ Health 32: 185–189 (1977).
8. Kanarek, M. S., et al.: Asbestos in drinking water and cancer incidence in the San Francisco Bay area. Am J Epidemiol 112: 54–72 (1980).
9. Meigs, J. W.: Assessment of studies on cancer risks from asbestos in Connecticut drinking water. Environ Health Perspect 53: 107–108 (1983).
10. Millette, J. R., et al.: Epidemiology study of the use of asbestos-cement pipe for the distribution of drinking water in Escambia County, Florida. Environ Health Perspec 53: 91–98 (1983).
11. Sadler, T. D., Rom, W. N., Lyon, J. L., and Mason, J. O.: The use of asbestos-cement pipe for public water supply and the incidence of cancer in selected communities in Utah. J Community Health 9: 285–293 (1984).
12. Hopkins, J.: Epidemiological studies on ingested asbestos. Food Chem Toxicol 22: 179–181 (1984).
13. Wagner, J. C.: Mesothelioma and mineral fibers. Cancer 57: 1905–1911 (1986).
14. Levine, D. S.: Does asbestos exposure cause gastrointestinal cancer? Dig Dis Sci 30: 1189–1198 (1985).
15. Patel-Mandlik, K., and Millette, J.: Accumulation of ingested fibers in rat tissues over time. Environ Health Perspec 53: 197–200 (1983).
16. Erdreich, L. S.: Comparing epidemiologic studies of ingested asbestos for use in risk assessment. Environ Health Perspec 53: 99–104 (1983).
17. Burnett, W. S., et al.: Cancer incidence by county, 1978–1982, New York State. New York State Department of Health, 1987.
18. Molina, E. C.: Poisson's exponential binomial limit. Robert E. Krieger, Co., Huntington, NY, 1973.

19. Diem, K., and Lenter, C., editors: Scientific tables, 7Ed. Ciba-Geigy Ltd., Basle, Switzerland, 1973, pp. 107-108, 189.
20. DeCoufle, P.: Occupation. *In* Cancer epidemiology and prevention, edited by D. Schottenfeld and J. F. Fraumeni. W. B. Saunders, Philadelphia, PA, 1982, pp. 318-335.
21. Newhouse, M. L., Berry, G., Wagner, J. C., and Turok, M. E.: A study of mortality of female asbestos workers. Brit J Ind Med 29: 134-141 (1972).
22. Wignall, B. K., and Fox, A. J.: Mortality of female gas mask assemblers, Brit J Ind Med 39: 34-38 (1982).

Correlates and Predictors of Serum Total Cholesterol in Adolescents Aged 12–17 Years: the National Health Examination Survey

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Synopsis

To examine correlates and childhood predictors of serum total cholesterol in adolescence, measures of growth, development, and obesity were related to serum total cholesterol levels of youths aged 12–17 years in the National Health Examination Survey. In this sample, drawn from the U.S. population, serum total cholesterol levels were negatively correlated with indicators of growth and maturation in males aged 12–14 years and positively correlated with overweight or obesity at all ages.

All measured variables could account for less than 15 percent of cholesterol variation in males and less than 6 percent in females. In white males, indicators of levels of maturation, growth, and changes in body fatness measured 28–53 months earlier were significant predictors of serum total cholesterol in adolescence, explaining 13 percent of its variation. Despite significant associations, indicators of growth, sexual maturation, and obesity explained only a small fraction of serum cholesterol variation in adolescents.

SERUM TOTAL CHOLESTEROL concentration is a major risk factor for coronary heart disease in adults (*1*). Arteriosclerotic changes may appear in the coronary arteries as early as the second and third decades of life (*2*). Furthermore, serum total cholesterol tracking has been demonstrated in adults and over followup periods of at least 9 years in children (*3-6*). Therefore, the determinants of serum total cholesterol in childhood and adolescence are of interest both for understanding the origins of coronary risk and for coronary prevention.

National population estimates have been published of serum total cholesterol levels in adolescents as well as the associations of cholesterol with age, sex, race, region, income, and education (*7-9*). Other correlates of serum total cholesterol in youths aged 12–17 years and childhood predictors of serum total cholesterol in adolescence were examined.

Methods

The third cycle of the National Health Examination Survey (HES) was conducted on a nationwide multistage probability sample of 7,514 youths from the noninstitutionalized population of the United States, aged 12–17 years. The survey started in March 1966 and ran until March 1970. Out of the 7,514 youths selected for the sample, 6,768 (90 percent) were examined. There were 5,735 whites, 999 blacks, and 34 others.

Details of the plan, sampling, response, and operation were published previously, as were procedures for informed consent and confidentiality of