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Subject: Paper on "Asbestos Cement Pipe and Cancer In Connecticut, 1955-1974" by Meigs et. al

The subject paper is forwarded herewith for information.

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Asbestos Cement Pipe and Cancer In Connecticut, 1955-1974

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Abstract

The associations of the use of asbestos-cement (A/C) pipe in public potable water distribution systems with changes in Connecticut cancer incidence rates were analyzed. Eight measurements related to asbestos in town water, population density, and socioeconomic scores were tested for their association with increased rates of cancer incidence, using multiple regression. No consistent patterns of association were found. The study provided no evidence for changing current water distribution policies for Connecticut public water supplies because of A/C pipe use.

Concern that the use of asbestos cement (A/C) pipe in public potable water distribution systems might increase the risk of gastrointestinal cancer has stimulated studies in Connecticut. A basis for this concern has been the evidence that persons occupationally exposed to airborne asbestos have experienced higher than expected rates of peritoneal mesothelioma, gastric cancer, and perhaps colon cancer. A study of 17,800 asbestos insulation workers showed a two to threefold increased risk of cancer of the oropharynx, esophagus, stomach, colon, and kidney, which might have been associated with clearance and swallowing of airborne fibers (1). Analyses of cancer rates in areas where asbestos fibers have been found in the drinking water have not produced clear evidence of excess cancer rates. Studies in Duluth, Minneapolis, and St. Paul, (2,3,4) and in the Puget Sound area (5) did not produce evidence that asbestos in water had contributed to increased cancer of any of the anatomical sites studied. In Quebec (6) and in five California counties (7) some positive associations were found for some digestive sites.

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Asbestos fibers are known to detach from asbestos-cement (A/C) pipe distribution mains in some situations. In A/C pipe systems in Florida, Pennsylvania, Kentucky, and South Carolina, asbestos (chrysotile) fiber concentrations of over 10 million fibers per liter have been found (8). It is thought that some of the factors related to the chemistry of the water passing through the pipe, such as the addition of corrosion control chemicals, may be related to the number of fibers eroded into the drinking water.

In many Connecticut townships A/C pipe has been used, totally or partially, for over 30 years. Counts of asbestos fibers in water systems were rarely over 1×10^6 fibers/liter. Measurements showed that 16% of fibers (chrysotile) were more than 5 micrometers (μm) in length and 11% were greater than $10 \mu m$. Since the preliminary investigation by Harrington et al. (9), which gave no indication that changes in the gastrointestinal cancer rates in Connecticut from 1935 through 1974 had been associated with the use of A/C pipe, substantially augmented information has become available (8). Further measurements of asbestos fibers in Connecticut town water supplies, and water quality information related to the potential for the leaching of asbestos fibers from A/C pipe into the water supply, have extended the data. The data have been analyzed with more powerful statistical methods in this study.

Materials and Methods

To assess the possible influences of A/C pipe use on cancer occurrence in Connecticut, individual town cancer rates were entered into a regression equation as the dependent variable, while asbestos exposure indicators for each town were entered as independent variables (10). Over 40 years of cancer incidence data are available to the Connecticut Cancer Epidemiology Unit from the Connecticut Tumor Registry by town of patient residence; therefore, the independent variables related to the drinking water, asbestos fibers and A/C pipe were prepared by town. Data from the periods 1955-64 and 1965-74 were used. Asbestos effects attributable to individual town asbestos-in-water concentrations would not be demonstrable before 1955 because little A/C pipe was used before that date. Our preliminary analysis had shown no detectable increases in cancer incidence when the later (after 1953) rates across the state, adjusted for A/C pipe use, were compared with the 1935-53 rates (9).

For each of the 169 Connecticut townships, the following information was used: number of newly

Table 1:

Association of cancer incidence (O/E) at 8 primary sites with cancer exposure from asbestos/cement (A/C) pipe, population density and socioeconomic status in Connecticut towns, 1955-1964, 1965-1974.

		MALE											FEMALE										
		Asbestos indicators											Asbestos indicators										
Site, ICD-O [a]	Time Period	b	c	d	e	f*	g	h*	i*	j	k	R^2	b	c	d	e	f*	g	h*	i*	j	k	R^2
All sites [m]	1									++		0.22					–				++	++	0.20
	2									++		0.32					– –		+		++	++	0.15
Stomach (151)	1										– –	0.24								+	++	–	0.22
	2										– –	0.24											0.06
Colon (153)	1								+	++	++	0.30							+		++		0.14
	2									+		0.14											0.07
Rectum (154)	1											0.11											0.06
	2											0.11		++									0.11
Pancreas (157)	1	+						++				0.17											0.07
	2			+	+							0.11											0.04
Trachea, bronchus, lung (162)	1									++		0.32									++	++	0.14
	2							++		+	– –	0.32		+			–		+	– –	++	++	0.16
Urinary bladder (188.0-188.6, 188.8, 188.9)	1							+				0.17		+	–					– –			0.22
	2											0.03											0.08
Kidney, renal pelvis, ureter (189.0-189.2)	1			+								0.06			+			+				++	0.18
	2										+	0.11											0.07

Table Notes

\+ indicates a positive association with higher asbestos exposure.
– indicates a negative association.
\+ or – = $p \leq 0.05$
++ or – – = $p \leq 0.01$
1. 1955-1964
2. 1965-1974

a "International Classification of Diseases for Oncology". WHO, 1976(18)
b Asbestos: fibers/liter x 10^6 in water, 1975.
c Percentage of town population on A/C pipe, 1975.
d Length of A/C pipe in miles per person, 1970.
e Maximum age of A/C pipe, 1960, 1970.
f Iron content in source water in mg./liter, 1975.*
g Change in calcium, mg./liter by mile, 1975.
h Corrosion control in use, 1975.*
i Water aggressiveness index: [pH + $\log_{10}$ (calcium hardness x alkalinity)] 1975.*
j Number of persons per square mile, 1960 or 1970.
k Town socioeconomic score, 1960 or 1970.
m All cancer sites, except non-melanomatous skin.
R^2: The square of the multiple correlation coefficient.
*For this variable, the higher the numeric value, the lower the supposed exposure to asbestos, therefore high association (+) with cancer incidence on this table indicates low values.

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The 10 variables were entered into the regression as independent variables, in order to consider the effect of each in the presence of the others upon the cancer rates. In a separate analysis, the six indicators of possible fiber leaching from A/C pipe were tested for correlation with the measured quantity of asbestos[4] in water.

Results

1. Associations of Cancer with Asbestos and A/C Pipe Variables

Eight cancer sites were analyzed for male and female experience separately, for the two time periods for 169 Connecticut towns. Results are shown in Table 1 for the 1960 period as the number 1 and for the 1970 period as the number 2. For three of the indicator variables, the lower the numeric value, the higher is the estimated risk of exposure to asbestos fiber: iron content, addition of chemicals for corrosion control, and the aggressiveness index. In Table 1, therefore, risk of exposure rather than numeric value is indicated by the + and − signs. The +(−) sign indicates a regression coefficient significant at the 5% level ($p < .05$) and ++(−−) indicates an association significant at the 1% level ($p < .01$). R^2 is the squared multiple correlation coefficient, which is an estimate of the proportion of the variation in the cancer rate associated with the independent variables.

Fairly consistent associations of certain cancer rates with town population density and SES are shown in Table 1. As population density increased, the "all sites" and lung cancer rates were higher in both men and women in both time periods. Colon cancer in the 1960 period was positively associated with population density both in men and women, and for men only in the 1970 period. A strong association of stomach cancer with density occurred in women in the 1960 period.

Socioeconomic scores of Connecticut towns were significantly negatively associated with stomach cancer in men both in the 1960 and 1970 periods, in women in the 1960 period, and with lung cancer in men in 1970. SES was also positively associated with male colon cancer in 1960, with lung cancer in females in 1960 and 1970, and with female kidney cancer in 1960. There was a strong positive association of SES for "all sites" of cancer in females in both periods.

There were a number of significant correlations between the asbestos-A/C pipe variables and the cancer rates. There were five associations out of 64 tests at $p \leq 0.05$ in the 1955-64 decade among men, and all indicated an increasing cancer incidence with an increase in the hypothesized risk factor. One cancer site, the pancreas, had two significant regression coefficients, one for lack of corrosion control in A/C pipe, the other for the level of asbestos fibers in water supply. ($R^2 = 17\%$). In 1970, pancreatic cancer in men again showed two significant regression coefficients, for age of A/C pipe and length of A/C pipe ($R^2 = 11\%$). There were no significant associations of pancreatic cancer incidence and A/C pipe factors among women in either time period.

There was a positive association of length of pipe with kidney cancer in both sexes in 1955-64. There were no significant kidney cancer associations with A/C pipe risk factors in 1970.

The other two positive associations in men, in the 1955-64 period, were lack of corrosion control for A/C pipe with bladder cancer, and high aggressiveness index of water with colon cancer. These were not observed elsewhere in either men or women.

Among men in 1965-74, in addition to the already noted positive associations for pancreatic cancer, there was a significant association of lack of corrosion control in A/C pipe with lung cancer incidence.

Among women in the 1955-64 decade, 8 significant associations with asbestos factors were observed, 5 positive and 3 negative, while in 1965-75 there were 4 positive and 3 negative associations. These showed no consistent pattern. For example, in the 1965-74 period, lung cancer in women showed a positive association with the percent of population served by A/C pipe, and negative associations with control of asbestos leaching by iron in water, and with the aggressiveness index of water.

The same analyses were carried out using only the 82 towns with some A/C pipe. Results were similar to those given in Table 1.

2. Associations of A/C Pipe Variables with Asbestos in Water:

To learn whether the measured quantity of asbestos in water was correlated with the indicators for asbestos in water, a second regression analysis was performed. The number of asbestos fibers per 10^6/liter, as measured for each town water sample delivered through A/C pipe, was the dependent variable, and the indicators of risk of asbestos in water were entered as independent variables, as follows:

x_1 = Iron content of water delivered through A/C pipe, mg/liter, 1975.

x_2 = Corrosion control chemicals added to water delivered through A/C pipe, 1975. Present or absent.

x_3 = Aggressiveness index at source for water delivered through A/C pipe, 1975.

x_4 = Change in calcium content, mg/liter per mile of A/C pipe, 1975.

x_5 = Maximum age of A/C pipe, 1975.

x_6 = Average length of A/C pipe per person served, 1975.

There was no significant relationship between any of the indicators for assumed asbestos fiber leaching from A/C pipe and asbestos fibers as actually measured.

Discussion and Conclusions

These analyses give no consistent indication that use of A/C pipe in Connecticut public water supplies has been followed by increases in incidence either of "all cancers" or of the individual sites considered. The observed associations between male pancreatic cancer rates and asbestos indicator variables are not consistent internally. That is, they were attributable to different indicator variables in the two decades, and were less significant in the later decade; whereas, they should have been greater if they had been causally related to asbestos. The associations of lung cancer with asbestos indicator variables were notable in that two of four significant associations among women were opposite to each other; that is, two indicated a "protective" effect on women's lung cancer rates from asbestos risk indicators.

Given the generally negative findings, it is important to estimate the power of the regression analysis; that is, to compute what strength of asbestos effect, had such existed, would have been identified in the size of data set used. It was found that if there had been a 50% additional risk of cancer (all sites) in those towns with the highest asbestos levels as compared to those with the lowest levels, the probability (or power) of detecting this would have been well over 90% for each decade and sex. For individual sites, the power is less because of the smaller number of cases; the weakest analysis is for an effect of asbestos on bladder or kidney tumors, where the power is approximately 50% to detect a 50% increase in risk, or about 80% of detecting a twofold increase. For each of the other sites the power was at least 80% of demonstrating a 50% increase in risk. These figures are all applicable when using the conventional 5% level for testing significance.

The analytical methods were considerably more refined and powerful than those in our previous study, and environmental information was more detailed. *Therefore, the lack of coherent evidence for cancer risks from use of A/C pipe is reassuring.* It is consistent with most reports from other areas of the United States. It is probably related to the fact that most Connecticut water supplies contained small concentrations of fibers and that the great majority of these fibers were shorter than 5 μm in length. Studies of diseases caused by asbestos have shown that fibers longer than 5 μm are more hazardous than shorter ones (17).

The methods for measuring asbestos fibers and for estimating the risks of leaching of asbestos from other water quality measurements are still relatively inaccurate. This was confirmed by the lack of intercorrelation of these postulated asbestos risk indicators in our study. Future work will require better methods for asbestos risk indicators as well as data on other trace contaminants, especially organics, that have been alleged to increase cancer risks. The results reported here provide no evidence for changing current water distribution policies for Connecticut water supplies because of A/C pipe use.

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BUREAU OF MINES MINERALS YEARBOOK

Asbestos

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES DEPARTMENT OF THE INTERIOR • James G. Watt, Secretary

BUREAU OF MINES • Robert C. Horton, Director

This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Asbestos

By R. A. Clifton[1]

Shipments of asbestos (all chrysotile) in 1981 from mines in the United States decreased 6% from those in 1980. Imports in 1981 were 3% higher than those in 1980.

U.S. apparent consumption declined 3% in 1981. Canadian shipments in 1981 were 14% lower than those for 1980. Shipments from Canada to the United States rose slightly during 1981. Imports from Canada were 94% of total U.S. imports in 1981, and those from the Republic of South Africa accounted for 5%.

Table 1.—Salient asbestos statistics

	1977	1978	1979	1980	1981
United States					
Production (sales) __ metric tons__	92,256	93,097	93,354	80,079	75,618
Value __ thousands__	$25,267	$27,987	$28,925	$30,599	$30,685
Exports and reexports (unmanufactured) metric tons__	34,896	45,380	r43,291	r48,671	64,419
Value __ thousands__	$12,075	$20,533	r$17,381	r$21,067	$21,508
Exports and reexports of asbestos products (value) do____	$62,665	$119,915	r$137,690	r$141,653	$145,130
Imports for consumption (unmanufactured) metric tons__	550,693	570,020	513,084	327,296	337,618
Value __ thousands__	$145,146	$154,351	$135,210	$91,809	$103,893
Released from stockpile (unmanufactured) metric tons__	188	--	1	--	--
Consumption, apparent[1] __ do____	609,157	618,706	560,600	358,700	348,800
World. Production __ do____	r4,793,451	r4,693,221	4,884,732	p4,887,215	e4,725,533

eEstimated. pPreliminary. rRevised.
[1]Measured by quantity produced, plus imports, plus stockpile releases, minus exports.

Legislation and Government Programs.—Regulatory agency procedures, proposals, and regulations, including asbestos related ones, were under review in 1981 to bring about conformance with Supreme Court decisions and new administration policy. Even prior to establishment of the Cabinet level Presidential Task Force on Regulatory Relief, Federal Register (F.R.) Jan. 30, 1981, the agencies had begun some changes. For example, the Occupational Safety and Health Administration (OSHA), in the January 19th F.R., published some final rule changes in the general cancer policy, and further changes were prepared in the January 23d F.R. The significant change proposed in the January 23d issue was that OSHA must consider all relevant evidence in making its determinations.

In the February 6th F.R., a Presidential memorandum postponing the promulgation of all regulations for 60 days was announced, and in the February 19th F.R., Executive Order 12291 requiring cost benefit analyses of all new and existing regulations was promulgated.

The Asbestos Information Association/North America presented to the Task Force on Regulatory Relief the following as those regulatory initiatives that most threaten the asbestos industry: (1) A proposal outstanding at OSHA since 1975 to reduce the permissible workplace exposure level from 2.0 to 0.5 fibers per cubic centimeter, and outstanding recommendations by the National Institute for Occupational Safety and Health to reduce that standard even further to 0.1 fiber; (2) announcement by advance notice of proposed rulemaking in 1979 at the Environmental Protection

Agency (EPA), under Section 6 of the Toxic Substances Control Act (TSCA), to consider the possibility of banning all industrial and commercial uses of asbestos; (3) announcement by advance notice of proposed rulemaking in 1979 at the Consumer Product Safety Commission (CPSC) to consider the possibility of banning all uses of asbestos in consumer products; (4) outstanding water-quality criteria for asbestos issued by EPA under the Clean Water Act that, although they do not yet have formal regulatory impact, have already created marketing problems for asbestos-cement pipe manufacturers; (5) a proposal by EPA under TSCA Section 8(a) to collect enormous amounts of information on asbestos in support of numerous efforts to regulate asbestos more stringently; (6) a proposal by EPA to identify asbestos in schools; and (7) plans by EPA to reassess the existing National Emission Standard for a Hazardous Air Pollutant asbestos regulation with the possibility of tightening its requirements.

On June 17, the U.S. Supreme Court handed down a decision in the cotton dust case. Interpretations of the decision vary as the AFL-CIO says that the ruling flatly cuts out cost benefit analyses, while OSHA contends that only the mandatory nature of such analyses is removed.

In the July 21st F.R., the EPA clarified which asbestos exports must be reported under the TSCA. EPA considers three categories of asbestos exports to be reportable: (1) bulk shipments of raw fiber; (2) an asbestos-containing mixture that assumes the shape of its container—for example, asbestos-containing paints; and (3) an asbestos-containing mixture that is formed to a shape that must be fundamentally changed before use. Given as examples of types of products that are not subject to the rule are asbestos-cement pipe, brake linings, sheet gasketing, unfinished asbestos textiles, floor tiling, and rolls of asbestos paper.

On December 7, the Supreme Court refused to review the separate rulings of Federal Appellate Courts that held that any insurer would be liable for health impairment claims during the period of exposure to asbestos as well as during manifestation of the disease.

Environmental Impact.—It is practically impossible to separate the large drop in 1980 in asbestos consumption into economic environmental parts. It would seem to be mainly economic, but the very large number of lawsuits about asbestos exposure-related diseases and their coverage in the media are bound to have some effect on the market. The scope of these effects was discussed by Senator Hart and printed in the Congressional Record. The Senator introduced into the Record an article from the National Law Journal (Oct. 19, 1981) entitled "The Asbestos Case Explosion" by James Granelli.[3] Mr. Granelli says that two recent Federal Appellate Court rulings and a recent medical study could radically expand the size and number of the asbestos-related disease lawsuits. These lawsuits are already the largest type of product-liability case in the country. Any "radical expansion" of the 12,000 to 15,000 cases pending (5,000 in California alone) could overwhelm the courts.

Seamen and shipyard workers, the largest group of plaintiffs, have been deemed by an October ruling of the 4th U.S. Circuit Court of Appeals to come under admiralty law; their suits can be tried in Federal courts, thereby avoiding the statute of limitations that bind many State courts.

On October 1, Judge David Bazelon, writing for the District of Columbia Circuit Court of Appeals, settled the hard-fought question of the "moment of liability" so important to the insurance carriers. He ruled that the insurance coverage was triggered both at the time of exposure and manifestation and also while the asbestos fibers were in residence.

The Johns Manville Corp. had 8,000 cases pending involving 13,500 plaintiffs and had settled 1,000 cases. The plaintiffs have won 56% of the cases that went to trial and were awarded amounts ranging from $16,000 to $1,857,600.

The disposal of 395 cases in 1980 by trial or settlement resulted in an average award of $76,000 to the plaintiffs. In the first 9 months of 1981, 302 cases were disposed of with an average cost of $58,500 per case to the defendant. A business publication suggested that in the long run, these cases may be a social rather than a legal problem.[3] It suggested that the huge scope of potential liabilities from asbestos and other latent diseases may be too great for an industry or group of industries to bear. The Government may have to step in. The inclusion of the tobacco industry and the Government itself as codefendants in many suits may influence congressional decisions.

According to one of its journals, the medical profession apparently thinks that environmental regulations are sometimes based on incomplete, inaccurate, or misinterpreted data.[4] Affairs of the American Medical Association (AMA) in their on "Carcinogen Regulations" gave the following as major conclusions: (1) Although such carcinogens as asbestos and chromates have been identified in the workplace, there is no definitive epidemiologic evidence that the United States has experienced an overall increase in the incidence of cancer related to high levels of pollutants or contaminants in the environment; (2) much more research relating the development of cancer in animals to a parallel development in humans is needed before that relationship can be used to mandate regulating substances in the human environment; (3) the AMA should continue to encourage Federal regulatory agencies to use an independent review process for full scientific assessment—one that will objectively consider experimental biases and define the limits of testing accuracy before a formal proposal is made to regulate a potential carcinogen; and (4) the AMA should advise Federal regulatory agencies of the importance of providing a comment period of at least 90 days after the proposal of a regulation so that there may be indepth peer review of the proposed policy or rule.

In 1981, the first drafts of the long awaited reports on the National Toxicology Program animal feeding study became available. They give no indication of carcinogenicity from ingested asbestos.

Table 2.—Stockpile goals and Government inventories as of December 31

(Metric tons)

	Stockpile goals	Total inventories			Sales of excesses, 1981
		1979	1980	1981	
Amosite	15,422	38,587	38,587	38,587	--
Chrysotile	2,722	9,034	9,034	9,034	--
Crocidolite	--	2,163	2,163	754	1,409
Total	18,144	49,784	49,784	48,375	1,409

DOMESTIC PRODUCTION

Mines in the United States shipped about 6% less asbestos in 1981 than in 1980, but the value was practically identical. Three States produced asbestos; California was the leader, followed by Vermont and Arizona. Total output was 75,618 tons valued at $30.7 million.

Calaveras Asbestos Corp. was California's and the Nation's leading producer from its Copperopolis Mine. One other mine was also active in California. On the Joaquin Ridge near Coalinga, in San Benito County, Union Carbide Corp. operated its Santa Rita Mine.

The Vermont Asbestos Group's Lowell Mine in Orleans County, Vt., is second in the country in production.

Arizona production in 1981 was below the 1980 level. The Jaquays Mining Corp. in Gila County had the only active asbestos mine in the State. This mine will probably be closed in 1982.

Employment in U.S. asbestos mines and mills averaged about 450 persons during 1981.

Table 3.—Asbestos producers in the United States in 1981

State and company	County	Mine	Type of asbestos
Arizona. Jaquays Mining Corp	Gila	Chrysotile	Chrysotile.
California:			
Calaveras Asbestos Corp	Calaveras	Copperopolis	Do.
Union Carbide Corp	San Benito	Santa Rita	Do
Vermont. Vermont Asbestos Group	Orleans	Lowell	Do.

CONSUMPTION AND USES

Total U.S. asbestos consumption decreased 3% from 1980 to 1981. Chrysotile was 90% of that consumed; crocidolite, 9%. Small amounts of both amosite and anthophyllite were reported used.

Asbestos-cement pipe decreased its share of the asbestos used from 40% in 1980 to 37% in 1981. Chrysotile was 76% of that

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