ported by a grant from the City of Birmingham, for his skillful assistance with the analytical work. They are also grateful to the staff of the City of Birmingham Dental Clinics for supplying teeth for analysis.

Accepted for publication June 26, 1976.

Article copies are available from Dr. Harry A. Waldron, Department of Social Medicine, The Medical School, Birmingham B15 2TJ, United Kingdom.

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PLAINTIFF'S EXHIBIT

ASA-844

Cancer Mortality in Relation to Asbestos in Municipal Water Supplies

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ABSTRACT

The mortality experience of twenty-two municipalities in Quebec grouped by evidence of exposure to asbestos fibers in water supplies (known high, possible high, and probable low exposures) was evaluated. Excess mortality due to cancer of the stomach (males), pancreas (females), and lung (males) was observed in t[illegible] municipalities with known high exposures. The excesses among males may have been due to occupational exposure to asbestos. The absence of excess mortality due to pancreatic cancer among males suggested that the excess among females was not due to waterborne asbestos. The study therefore did not reveal evidence of excess cancer mortality that could be attributed to exposure to asbestos in drinking water.

ALTHOUGH ASBESTOS is a well-characterized carcinogenic agent when inhaled by humans,[1] there is little evidence concerning its carcinogenicity when ingested. Asbestos fibers were discovered in Lake Superior, the source of municipal water for Duluth, Minnesota, in 1973. Further investigation revealed the presence of 1-30 million amphibole asbestiform fibers per liter in Duluth tap water samples. Contamination of the water supply with asbestos apparently began in 1955 as a result of the dumping of taconite mine-tailings into the lake. Thus, the studies referred to below[2,3] probably did not include a sufficient time period to observe an increased risk of cancer due to exposure to waterborne asbestos.

A study of cancer mortality[2] during four 5-year periods beginning in 1950 revealed that, relative to the state of Minnesota, the city of Duluth had significant excess mortality due to several cancer sites at least one time period. The gastrointestinal sites involved were cancers of the esophagus, stomach, and rectum in white males, and cancers of the rectum and pancreas in white females. However, only the rate for male rectal cancer increased during the time periods subsequent to 1955-59; the female rectal cancer rate increased between 1950-54 and 1955-59, that is, before or soon after the dumping of taconite tailings began. An interval of 10 to 20 or more years before development of cancer would be expected for most human carcinogens.

ASARCO ELP 0004111

In another study, incidence rates during 1969-71 were significantly high in Duluth compared with Minneapolis for stomach cancer (males) and compared with either Minneapolis or St. Paul for cancer of the pancreas (both sexes), but were significantly lower in Duluth than in either comparison city for cancer of the large intestine.[3]

The present study was undertaken to evaluate cancer mortality in two municipalities, Thetford Mines and Asbestos, where asbestos mining operations were established many years ago, in 1878 and 1882, respectively. Recent studies[4] (R. W. Durham 1975: personal communication) have revealed the presence of relatively high concentrations of asbestos fibers in the municipal water supplies of Thetford Mines and Asbestos. The asbestos deposits in the region of these municipalities consist mainly of chrysotile in serpentinized peridotite.[5]

Method

Tabulations of the number of deaths by three-digit rubrics of the *International Classification of Diseases*, seventh revision (1964-68) and eighth revision, adapted for use in the United States (1969-73), 5-year age group, sex, and municipality were obtained from the Health Division of Statistics Canada. The 1966 and 1971 populations by age, sex, and municipality were obtained from the Census Data Dissemination Division of Statistics Canada.

The municipalities included are as follows: In Group 1 (known high exposure)—Asbestos and Thetford Mines; in Group 2 (possible high exposure)—Black Lake, Drummondville, Drummondville Sud, Magog, Plessisville, Victoriaville, and Windsor; in Group 3 (probable low exposure)—Alma, Arvida, Bécancour, Grand' Mère, Joliette, La Tuque, Nicolet, Rimouski, Rimouski Est, Rivière-du-Loup, Shawinigan, Shawinigan Sud, Sorel-Tracy, St. Hyacinthe, St. Jérôme, and Ste. Thérèse.

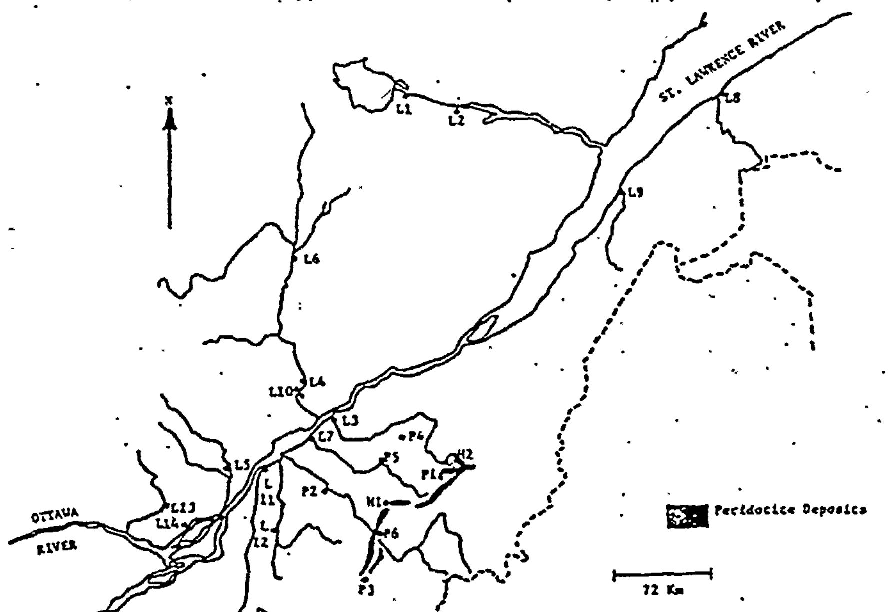
The expected numbers of cancer deaths were calculated by applying the Quebec age-specific (5-year groups), sex-specific, site-specific, and period-specific (1965-67, 1970-72) mortality rates to the 1966 or 1971 census populations by age and sex for each municipality.

Results

Characteristics of Grouped Municipalities

The locations of the municipalities in each of the three groups are shown on the map in the figure. The two towns with known high exposures (Group 1) and the six towns with possible high exposures (Group 2) are clustered within a radius of about 40 miles and either are immediately adjacent to asbestos-containing deposits or obtain drinking water from rivers draining the region of such deposits. Towns with probable low exposures (Group 3) were selected from regions remote from the peridotite deposits shown in the figure. The available data concerning the concentration of asbestos fibers in the municipal water supplies are presented in Table 1. The results for Asbestos and Thetford Mines indicate asbestos fiber concentrations substantially higher than those for Drummondville (filtered) or Plessisville. There is a large discrepancy in the values reported by the two sources for Thetford Mines, but both values are high.

Selected demographic characteristics of the three



Location of municipalities and peridotite deposits. *H1*, Asbestos; *H2*, Thetford Mines; *P1*, Black Lake; *P2*, Drummondville and Drummondville Sud; *P3*, Magog; *P4*, Plessisville; *P5*, Victoriaville; *P6*; Windsor; *L1*, Alma; *L2*, Arvida; *L3*, Bécancour; *L4*, Grand' Mère; *L5*, Joliette; *L6*, La Tuque; *L7*, Nicolet; *L8*, Rimouski and Rimouski Est; *L9*, Rivère-du-Loup; *L10*, Shawinigan and Shawinigan Sud; *L11*, Sorel-Tracy; *L12*, St. Hyacinthe; *L13*, St. Jérôme; *L14*, Ste. Thérèse.

Table 1.—Available Data for Asbestos Fibers in Municipal Water Supplies

Municipality and Type of Water Supply Source	Reported Concentrations * of Asbestos Fibers in Municipal Water Supply
Asbestos	
Raw	1,200,000,000†
Filtered	200,000,000†
Thetford Mines	
Raw	172,000,000‡§
Raw	1,300,000,000†§
Drummondville	
Raw	680,000,000†
Filtered	1,100,000†
Plessisville	
Raw	13,000,000†§

* Fibers per liter.
† R. W. Durham 1975: personal communication.
‡ See reference 4.
§ Municipal water supply is not filtered.

Table 2.—Characteristics of Grouped Municipalities

Characteristic	Group 1 (Known High Exposure)	Group 2 (Possible High Exposure)	Group 3 (Probable Low Exposure)
Number of municipalities	2	6	14
Population*			
Average	15,857	15,603	21,028
Total	31,714	93,620	294,396
Percentage with French as mother tongue	95.9	97.2	96.6
Percentage in major occupation groups†			
11-33	17.2	15.8	18.9
41-61	30.5	33.2	33.7
77	11.1	0.8	0.1
81-85	16.2	26.8	19.9
Other	25.0	23.3	27.4

*By 1971 census.
† 11-33—managerial, professional, artistic, literary, recreational; 41-61—clerical, sales, service; 77—mining, quarrying; 81-85—processing, machining, product fabricating. Values shown represent the percentage of the experienced labor force, aged 15 years and over, for both sexes, in 1971.

groups of municipalities are presented in Table 2. The three groups were quite similar with respect to mother tongue (French) and proportions of the labor force employed in major occupational groups 11-33 (professional, administrative) and 41-61 (clerical, sales, service). The average population was somewhat larger for Group 3 than for Group 1 or 2. Groups 1 and 2 had the highest proportions of the labor force in major groups 77 (mining, quarrying) and 81-85 (processing, machining, product fabricating), respectively.

General Mortality

The observed (O) and expected (E) numbers of deaths due to all cancer and all other causes by municipality group and sex are presented in Table 3. Significant excesses of cancer deaths were observed among males in Group 1 (O/E = 1.23) and females in Group 3 (O/E = 1.07). There were significant excesses of deaths due to all other causes among males in all three municipality groups (O/E = 1.12, 1.08, and 1.10) and among females in Group 3 (O/E = 1.10).

The distribution of mortality was also studied for the individual municipalities within each of the three groups (data not shown but available upon request). Significant excesses of deaths due to all cancer were observed as follows: Group 1—Thetford Mines (males, O/E = 1.3); Group 3—Joliette (males, O/E = 1.3), La Tuque (males, O/E = 1.3), Nicolet (females, O/E = 1.8), St. Hyacinthe (females, O/E = 1.2), and Ste. Thérèse (females, O/E = 1.5). The municipalities having significant excesses of deaths due to all other causes were: Group 1—Asbestos (males, O/E = 1.2); Group 2—Drummondville (males, O/E = 1.1); Group 3—Alma (females, O/E = 1.4), Joliette (males, O/E = 1.3; females, O/E = 1.1), Nicolet (females, O/E = 1.5), Rivière-du-Loup (males, O/E = 1.2), Sorel-

Table 3.—Mortality Due to All Cancer and All Other Causes

Cause of Death, and Sex	Group 1 (Known High Exposure)			Group 2 (Possible High Exposure)			Group 3 (Probable Low Exposure)		
	Obs	Exp*	O/E	Obs	Exp	O/E	Obs	Exp	O/E
All cancer									
M	195	158.4	1.23‡	457	466.0	0.98	1,433	1,389.8	1.03
F	127	138.2	0.92	415	408.9	1.01	1,302	1,219.8	1.07†
T	322	296.6	1.09	872	874.9	1.00	2,735	2,609.6	1.05†
Other causes									
M	601	536.2	1.12‡	1,690	1,562.1	1.08‡	5,148	4,679.1	1.10‡
F	259	285.4	0.91	898	858.3	1.05	2,809	2,548.3	1.10‡
T	860	821.6	1.05	2,588	2,420.4	1.07‡	7.957	7,227.4	1.10‡

NOTE: The 25-74 age group was considered.
*See Methods section of text.
†$P < .05$, by the chi-square test.
‡$P < .01$, by the chi-square test.

Tracy (males, O/E = 1.1), St. Hyacinthe (males, O/E = 1.1; females, O/E = 1.1), and Ste. Thérèse (females, O/E = 1.2).

Cancer Mortality

The observed and expected numbers of cancer deaths by sex, site, and municipality group are presented in Table 4. Significant excesses of cancer deaths were observed as follows: Group 1—stomach (males), pancreas (females), lung (males); Group 2—prostate (males), kidney (females), brain (males), lymphoma (females); Group 3—large intestine except rectum (females), uterus except cervix (females), and kidney (females).

The distribution of gastrointestinal cancer by age group, sex, and aggregated sites is presented in Table 5. Significant excesses of cancer deaths were observed for the following: Group 1—upper gastrointestinal (females aged 75 and over, and total); Group 3—large intestine and rectum (males aged 75 and over); and total gastrointestinal (males aged 75 and over).

Discussion

Studies of workers exposed to asbestos have revealed excess mortality due to gastrointestinal cancer[6,7] and abdominal mesotheliomas.[6-9] Such observations may indicate that exposure to asbestos via the gastrointestinal tract (presumably from swallowed sputum in workers exposed to airborne asbestos) increases the risk of cancer

Table 4.—Cancer Deaths by Sex and Major Site

Cancer Site	Sex	Group 1 (Known High Exposure)			Group 2 (Possible High Exposure)			Group 3 (Probable Low Exposure)		
		Obs	Exp*	O/E	Obs	Exp	O/E	Obs	Exp	O/E
Buccal cavity and pharynx	M	4	5.8	0.7	11	17.0	0.6†	54	50.8	1.1
	F	1	1.5	...	3	4.4	...	9	13.0	0.7
Esophagus	M	3	3.5	...	5	10.5	0.5†	26	30.8	0.8
	F	1	1.1	...	2	3.2	...	3	9.5	0.3†
Stomach	M	24	17.4	1.4†	47	51.6	0.9	145	153.6	0.9
	F	10	8.7	1.2	35	26.0	1.3	91	77.1	1.2
Large intestine except rectum	M	18	14.0	1.3	41	41.0	1.0	126	122.2	1.0
	F	14	16.8	0.8	57	50.5	1.1	176	149.4	1.2†
Rectum	M	4	7.0	0.6	20	21.3	0.9	51	61.5	0.8
	F	4	5.0	0.8	9	14.8	0.6†	44	43.8	1.0
Pancreas	M	8	8.4	1.0	29	24.8	1.2	91	74.2	1.2
	F	9	5.2	1.7†	18	15.7	1.1	44	46.8	0.9
Lung	M	78	46.8	1.7‡	106	137.5	0.8‡	392	409.9	1.0
	F	10	7.7	1.3	17	22.9	0.7	54	68.5	0.8
Breast	F	29	35.0	0.8	106	98.8	1.1	303	305.5	1.0
Cervix uteri	F	7	8.7	0.8	26	25.0	1.0	74	75.3	1.0
Other uterus	F	7	7.1	1.0	19	21.1	0.9	80	62.3	1.3†
Ovary	F	9	8.6	1.0	22	25.4	0.9	75	75.8	1.0
Prostate	M	9	7.7	1.2	44	24.1	1.8‡	81	70.9	1.1
Kidney	M	2	3.8	...	9	10.9	0.8	28	32.6	0.9
	F	2	2.1	...	10	6.3	1.6†	24	18.9	1.3†
Bladder	M	4	6.0	0.7	10	18.0	0.6†	51	53.0	1.0
	F	1	1.5	...	2	4.5	...	11	13.4	0.8
Brain	M	2	4.8	...	25	13.3	1.9‡	42	40.3	1.0
	F	1	3.6	...	5	10.5	0.5†	37	31.7	1.2
Lymphoma	M	6	8.8	0.7	30	25.0	1.2	86	74.5	1.2
	F	3	6.5	0.5	24	19.2	1.3†	59	57.5	1.0
Leukemia	M	6	5.4	1.1	18	15.7	1.1	56	46.9	1.2
	F	2	3.7	...	9	10.9	0.8	35	32.6	1.1
Other	M	27	19.0	1.4†	62	55.3	1.1	204	167.6	1.2‡
	F	17	15.4	1.1	51	49.7	1.0	183	138.7	1.3‡

NOTES: Only the 25-74 year age group was considered. O/E was not calculated if E (expected number of deaths) was less than 5.
*See Methods section of text.
†$P < .05$, by the chi-square test if $E \geq 20$ and by Poisson distribution if $E < 20$.
‡$P < .01$, by the chi-square test if $E \geq 20$ and by Poisson distribution if $E < 20$.

Table 5.—Gastrointestinal Cancer Mortality By Aggregated Sites, Age, and Sex

			Group 1 (Known High Exposure)			Group 2 (Possible High Exposure)			Group 3 (Probable Low Exposure)		
Cancer Site	Sex	Age	Obs	Exp*	O/E	Obs	Exp	O/E	Obs	Exp	O/E
Upper gastrointestinal§	M	25-74	31	26.8	1.2	63	78.9	0.8	225	235.0	1.0
		75+	11	10.7	1.0	51	39.1	1.3	118	106.8	1.1
		Total	42	37.5	1.1	114	118.0	1.0	343	341.8	1.0
	F	25-74	12	11.2	1.1	40	33.5	1.2	103	99.5	1.0
		75+	11	5.3	2.1†	27	22.6	1.2	70	70.9	1.0
		Total	23	16.5	1.4†	67	56.1	1.2	173	170.4	1.0
Large intestine and rectum	M	25-74	22	20.9	1.1	61	62.3	1.0	177	183.7	1.0
		75+	3	8.8	0.3†	33	32.5	1.0	115	89.4	1.3‡
		Total	25	29.7	0.8	94	94.8	1.0	292	273.1	1.1
	F	25-74	18	21.8	0.8	66	65.2	1.0	220	191.6	1.1
		75+	8	9.7	0.8	39	41.5	0.9	136	130.0	1.0
		Total	26	31.5	0.8	105	106.7	1.0	356	321.6	1.1
Total	M	25-74	53	47.7	1.1	124	141.2	0.9	402	418.7	1.0
		75+	14	19.5	0.7	84	71.6	1.2	233	196.2	1.2‡
		Total	67	67.2	1.0	208	212.8	1.0	635	614.9	1.0
	F	25-74	30	33.0	0.9	106	98.7	1.1	323	291.1	1.1
		75+	19	15.0	1.3	66	64.1	1.0	206	200.9	1.0
		Total	49	48.0	1.0	172	162.8	1.1	529	492.0	1.1

*See Methods section of text.
†$P < .05$, by the chi-square test if E (expected number of deaths) ≥ 20 and by Poisson distribution if $E < 20$.
‡$P < .01$, by the chi-square test if $E \geq 20$ and by Poisson distribution if $E < 20$.
§Buccal cavity, pharynx, esophagus, and stomach.

in tissues directly or indirectly exposed to the fibers. This possibility has caused some concern about the presence of asbestos fibers in municipal water supplies both in the United States[2,3] and in Canada.[4,10]

The present study revealed some evidence of excess mortality due to gastrointestinal cancer in the two municipalities in Group 1 (known to have water supplies containing high concentrations of asbestos fibers). The individual sites for which there were statistically significant excesses of gastrointestinal cancer in these two municipalities were the stomach (males) and the pancreas (females). In Duluth, a significantly high incidence of pancreatic cancer was observed in both sexes. The present study does not support an association between pancreatic cancer and exposure to asbestos fibers in drinking water, because there was no excess among males. The excess stomach cancer among males may reflect occupational exposure to asbestos; the absence of an excess among females argues against a role for waterborne asbestos. Excess mortality due to stomach cancer has previously been observed in asbestos workers.[6,7]

The excess male mortality due to lung cancer observed for the two municipalities in Group 1 (Asbestos and Thetford Mines) was mainly due to an excess in Thetford Mines (O = 58, E = 31.6). This observation is consistent with the reportedly higher prevalence of opacities, pleural thickening, and pleural calcification, as diagnosed by chest roentgenography of asbestos workers,[11] in Thetford Mines than in Asbestos.

The substantial excesses of deaths due to prostatic and brain cancer among males in Group 2 municipalities (possible high exposure to asbestos) deserve further investigation, but do not appear to be related to waterborne asbestos since similar excesses were not observed in Group 1, and the excess of brain cancer in Group 2 was confined to males.

Conclusion

A study of twenty-two municipalities in Quebec did not reveal excess cancer mortality that could be related to the presence of asbestos fibers in drinking water supplies. Excess mortality due to stomach and lung cancer among males in two municipalities (Asbestos and Thetford Mines) may reflect occupational exposure to asbestos.

* * * * * * * * * *

The tabulation of mortality data by John Silins and Pio Uran and the assistance in data analysis by M. Honora Smith are gratefully acknowledged.

Submitted December 21, 1976; accepted for publication February 28, 1977.

Article copies are available from Dr. Wigle at the Bureau of Epidemiology, L. C. D. C., Health and Welfare Canada, Tunney's Pasture, Ottawa, Ontario, K1A OL2, Canada.

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