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Ambient Air Concentrations of Asbestos Fibers Near the Town of Asbestos, Québec

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Ambient air concentrations of asbestos fibers were measured during the period June 20 to August 12, 1980, at three locations; Danville, Asbestos, and Wottenville in the eastern townships of Quebec. Measurements were done with low-volume samplers and measurement periods extended from 3 to 13 days. Fiber counts were done by means of electron microscopy. Results indicate that overall fiber concentrations are related to atmospheric stability and to the direction of the prevailing wind with respect to the source of emission. © 1985 Academic Press, Inc.

INTRODUCTION

The commercial mining of asbestos, whether of the serpentine or the amphibole variety, leads to several types of hazards and inconveniences, one of the major of these being the pollution of the ambient air. Emanations into the ambient air normally occur during mining of the mineral, transportation of the raw fibers, and the various manufacturing processes utilizing asbestos as a raw material. The dangers to health, especially the incidence of asbestosis, a type of pneumonoconisis or disease of the lung, pleural and peritorial mesothelioma, and even lung cancer and other diseases arising from these airborne fibers have been already well documented (National Institute for Environmental Health, 1973; McDonald and McDonald, 1975; Buchanan, 1979; Jones, 1979; Capel, 1979; Newhouse, 1979; Levine *et al.*, 1979; Selikoff and Hammond, 1979). This risk to human health arises mainly from the inhalation of asbestos fibers that are contained in the ambient air. In the eastern townships of Quebec, the dominant fiber is of the chrysotile variety belonging to the serpentine mineral group. Chrysotile fibers are typically curved in appearance and occur in open bundles which tend to split into fibers and fibrils (Charlebois, 1978). The dimensions of these fibers and fibrils tend to vary in both length (ranging from 1000 Å to tenths of millimeters (Nicholson *et al.*, 1970)) and in diameter (ranging from 20 to 40 nm (Charlebois, 1978)). In addition, chrysotile fibers, which are generally white in appearance, have a specific gravity of 2.4–2.6 at room temperature, a tensile strength of 562–579 mg/m^2, and have a relatively low resistance to acid breakdown. At the town of Asbestos where there exists a single open-pit mine whose area is about 3 km^2, total annual production in 1976 was 600,000 metric tons (Brulotte, 1976).

In our study we monitored ambient air concentrations of asbestos fibers at three locations during the summer of 1980; at Asbestos where the mine is located, at Danville which lies to the west, and at Wottenville which lies to the east. Fiber counts were performed by means of electron microscopy. Variations in fiber con-

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centrations in time and space were examined with respect to prevailing meteorological conditions, mainly atmospheric stability and turbulence and horizontal wind speed and direction.

ATMOSPHERIC DIFFUSION

Ambient air concentrations of asbestos fibers represent the normal background concentrations for the region in question (Sébastien *et al.*, 1979) plus local pollution which, under specified conditions, can exceed background concentrations by several orders of magnitude (Bruckman and Rubino, 1977). Local pollution is mainly the result of the difficulty in reducing the emissions of fine particles of asbestos during excavation and factory operations (Harwood *et al.*, 1975), emissions that occur during transport of the asbestos mineral from mines to factories and thence to waste disposal sites (Harwood, 1971), and emissions from open pits and disposal sites (Ase *et al.*, 1976). In addition, one can mention the emissions associated with workers involved in the various mining and manufacturing activities who transport and liberate fibers from their clothes and body. In this study, the focus is on local pollution, that is to say on fibers emanating from a local point source.

Two classes of factors generally determine the level of air pollution at a particular location. First, there is the nature of the relevant emissions and of the source regions. Such distinguishing characteristics as the physical, chemical and geometric properties of asbestos fibers, as have been described above, are critical. The actual release of these fibers into the ambient air is essentially accomplished through mining operations such as blasting, factory operations such as crushing, and transport of such materials as crushed serpentine rocks and tailings in open-bodied trucks. We find it appropriate to describe the source region as an extended or large point source whose boundaries are delineated by the extent of the mining pits and adjoining milling plants and of the disposal sites (see Fig. 1).

Second, there is the state of the atmosphere. Wind can accelerate and even initiate the release of fibers into the air. After release into the ambient air, however, further dispersion of the fibers is strictly controlled by atmospheric turbulence and wind speed. The intensity of turbulent diffusion that is mechanically generated depends upon the horizontal wind speed as it influences internal shearing between moving air layers and upon surface roughness as it controls frictional shearing between the ground and the wind. The turbulent eddies generated in this manner are characteristically smaller. Thermal diffusion on the other hand, whose turbulent eddies are typically larger, is essentially a function of surface heating, mainly through solar radiation receipt and absorption. Generally if the size of the turbulent eddies is smaller than the cloud of fibers, they will diffuse it; if they are larger, they will tranpsort it (Shaw and Munn, 1971).

The wind field is critical with respect to horizontal dispersion. The wind speed determines both the distance of downwind transport and the amount of pollutant dilution, whereas the wind direction controls the path across which the pollutants are diffused and transported. When wind is blowing, asbestos fibers are dispersed both in the along-wind direction and by turbulent eddy diffusion in the across-wind and vertical directions. Atmospheric stability however, as characterized

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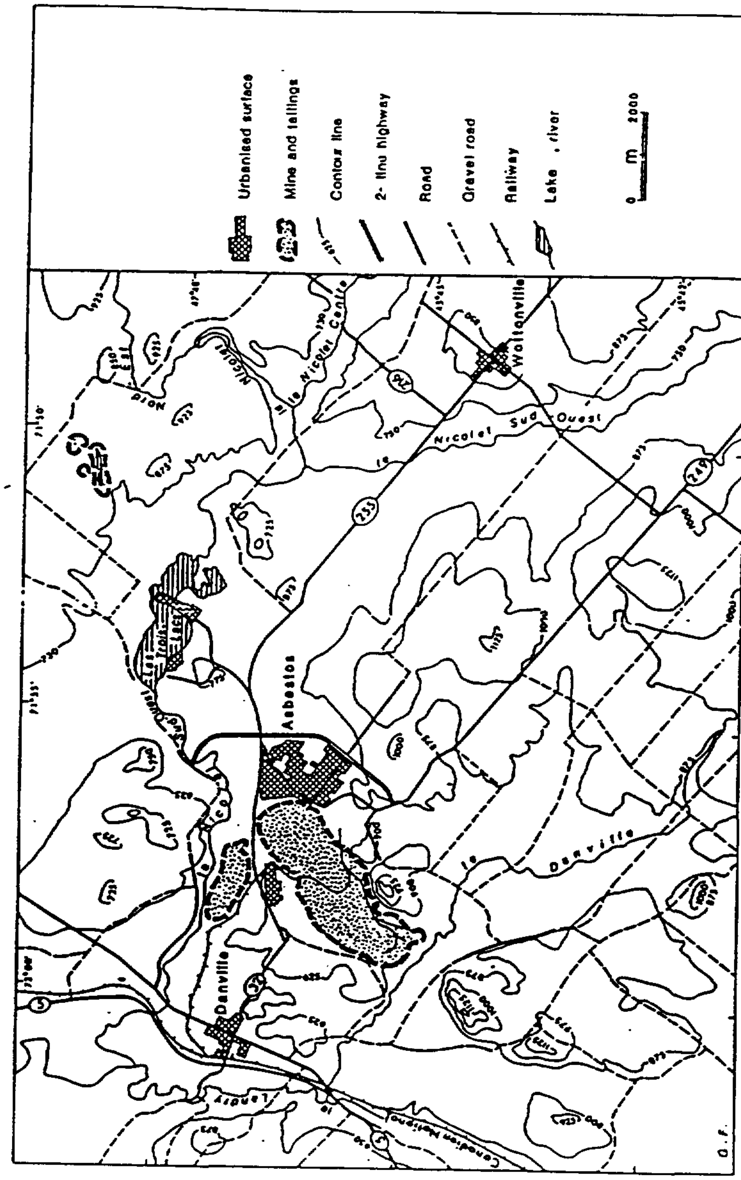

FIG. 1. General site of research.

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by the ambient air thermal stratification not only controls the intensity of turbulence and wind speed but also the depth of the surface mixed layer. This latter factor is critical in determining the extent of the vertical dispersion of fibers.

METHODS AND ANALYSES

Ambient air concentrations of asbestos fibers were measured during the period 20 June to 12 August 1980 at three locations in and around the open-pit Jeffrey mine located near the town of Asbestos, Quebec (Fig. 1). The area is fairly uniform topographically with elevations ranging from about 210 to about 375 meters (Fig. 1). The first site, at Danville, was about 3 km west of the mine and the tailing disposal site. The sampling equipment was located in a fairly extensive grass-covered open site adjoining the town's municipal building. The second site was at Asbestos, a town situated on the eastern extremity of the mining site. The sampling equipment was installed on the roof of the town's municipal building, an elevation of about 10 meters. Wind speed and direction were also measured at this location. The third site was located at Wottenville, a rural town situated about 11 km east-south-east of the mining site. The sampling equipment was located in an open site among cultivated fields.

The monitoring of ambient air concentration of asbestos fibers was performed by means of low-volume air samplers designed by Sébastien *et al.* (1979) and modified by the Institute of Occupational Health and Safety, McGill University. The face velocity of this sampler, using a Gast Rotary Carbon Vane pump, is 8.4 cm s^{-1}. This gives a flow rate of about 5 liter min^{-1}. The effective filter area is roughly 962 mm^2, with a diameter of about 47 mm. Upon this base filter was placed a metrical membrane filter of pore size 0.8 μm and diameter 47 mm for the collection of fibers. The height above ground or roof top, of samplers, was about 1.5 m. Samples were collected at intervals that varied from 2 to 6 days according to the sequence of weather conditions, except for one instance where the sampling period lasted 13 days because of the absence of an operator. Unfortunately, the sampler at the Asbestos site broke down after 2 weeks of operation and as a result, data for this site is missing after 4 July. Upon retrieval, the filters, with fibers attached, were enclosed in sealed containers, kept as immobile as possible and stored at room temperature.

The preparation of grids for counting of fibers via electron microscopy followed very closely the method suggested by Sébastien *et al.* (1978). A portion (1 cm^2) of each filter, on the surface of which were deposited the asbestos fibers, was removed. These were then inserted into conical Pyrex tubes which were then placed in a low-temperature asher (LTE 507) and subjected to activated oxygen for a period of about 6 hours. When ashing was complete, the residue was resuspended in 100 ml of specially filtered distilled water. To facilitate the counting of fibers, the residue was then ultrasonified for 15 min in an attempt to separate bundles into single fibers.

The liquid mixture containing the chrysotile fibers was then filtered through a polycarbonate nuclepore membrane (pore size, 0.1 μm; effective diameter, 35 mm). After drying, a portion of the filter was coated with a carbon film that was deposited via evaporation in an enclosed vacuum. Portions of the coated filter

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were placed directly on 200-mesh electron microscope grids. Two grids were prepared for each sample.

A transmission electron microscope was then used for counting the fibers on each of the two grids. Fibers were identified according to their geometric properties: fibril appearance and hollowed cylindrical ends. Magnification ranged from 2000 to 10,000 times by increments of 2000 and from 10,000 to 50,000 times by increments of 10,000.

For each grid, five fields, each measuring 80 × 80 μm, were chosen for measurement of the number and length of fibers according to the criteria described previously.

Fiber counts, expressed as a mass concentration, were derived in the manner described below (Gibbs and Rowlands, 1980; Gibbs and Hwang, 1975). First the number of fibers per liter of air sampled (FV) was derived as

$$FV = \frac{\Sigma T \times \text{EFA} \times 9.62}{\text{ST} \times FR} \ (\text{liter}^{-1}) \qquad (1)$$

where

FV = number of fibers per liter (liter^{-1}),
ΣT = total fiber count for the 5 fields chosen,
EFA = the effective filter area (962 mm^2),
ST = total surface area of the 5 fields chosen (32,000 μm^2),
FR = total volume of air (liters).

The factor EFA represents the total effective area of the original 35-mm filter and the factor 9.62 represents a dilution factor since samples of the original filter (100 mm^2) were redeposited upon a larger filter area (962 mm^2).

In order to arrive at the final value of fiber concentration, the following relationship was exploited (Gibbs and Rowlands, 1980)

$$FC = (FV \times 10^3) \times (2.5 \times 10^{-3}) \times ((\bar{D}/2)^2 \times \pi \times L\bar{X}) \ (\text{ng m}^{-3}) \qquad (2)$$

where

FC = fiber concentration in ng m^{-3},
$\bar{D}$ = mean diameter of each fiber, here chosen to be 0.08 μm,
$L\bar{X}$ = mean length of fibers (μm).

In the above equation (2), the first term converts liters (liters^{-1}) to cubic meters (m^{-3}); the second term represents the density of chrysotile fibers (ng m^{-3}); and the last term represents the total volume of fibers (μm^3).

During the period of data collection, wind speed and direction and general synoptic conditions relating to sky condition, air temperature, and humidity were recorded at the Asbestos site. In addition, the surface synoptic charts and the corresponding tephigrams were analyzed so as to derive estimates of atmospheric stability. Wind speed and direction and air temperature and its corresponding dewpoint, together with the degree of cloud cover, were extracted from the synoptic charts. The vertical temperature lapse rate and the mixing height were

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calculated from the change of vertical temperature gradient which was obtained from one of the surrounding stations where this data is available, i.e., Maniwaki, Quebec, Portland, Maine, or Albany, New York. The choice of station depended on the direction of air movement shown on the synoptic charts.

Two indices of stability, chosen on the basis of their relativeness to the study and of the availability of data, were then calculated. The first stability parameter has been proposed by Shaw and Munn (1971). They state that over relatively uniform surfaces, as are found in our study area, an appropriate stability parameter is the dimensionless stability index (SI) which incorporates both buoyancy and wind effects and which is expressed as

$$SI = \frac{\frac{g}{T} Z^2 \left(\frac{\partial T}{\partial Z} - \Gamma\right)}{\bar{u}^2} \qquad (3)$$

where

g = acceleration due to gravity (m sec^{-2})
T = temperature of ambient air (°K) near the ground (Z m)
$\frac{\partial T}{\partial Z}$ = the vertical temperature lapse rate (°K m^{-1})
Γ = adiabatic lapse rate (°K m^{-1})
$\bar{u}^2$ = mean horizontal wind speed (m sec^{-1})
Z = height of $\bar{u}$ (m).

Furthermore Shaw and Munn (1971) suggested the use of another index of atmospheric diffusion, namely the ventilation coefficient VC (m^2 sec^{-1})

$$VC = MH \times \bar{u} \qquad (4)$$

where

MH = the mixing height of the turbulent layer (m).

Because the wind speed does not change much with height in the turbulent layer, the parameter VC represents the rate of horizontal diffusion of fibers.

Following the lead of Islitzer (1965) and of Pasquill and Smith (1971), the indices of stability, as calculated by equation (4), are then related to Pasquill's (1961) stability classes so as to arrive at a more descriptive, yet objective, characterization of atmospheric stability (see Table 4).

DISCUSSION OF RESULTS

Tables 1, 2, and 3 summarize the relevant data and the final calculation of the concentration of asbestos fibers for the three stations under study. Due to instrument malfunction, data are missing for Asbestos from the 4th of July onward and for Wottenville from the 27th of June to the 4th of July. However, it is evident from the available data that generally the highest concentrations occurred at Asbestos and the lowest at Danville (see Table 5) due to downwind distance from the mining area.

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TABLE 1

SUMMARY OF RELEVANT DATA FOR CALCULATING AMBIENT AIR CONCENTRATION OF FIBERS: DANVILLE

Sampling period (1980)	n	Σ_1	$L\overline{X}_1$	Σ_2	$L\overline{X}_2$	Σ_3	$L\overline{X}_3$	Σ_4	$L\overline{X}_4$	Σ_5	$L\overline{X}_5$	ΣT	$L\overline{X}$	Fiber concentration (ng m^{-3})*
20–23 June	1	28	0.437	12	1.660	12	0.718	17	0.384	15	0.066	84	0.681	14
	2	31	0.579	8	0.551	6	0.717	20	0.465	15	0.908	80	0.619	13
23–27 June	1	5	0.292	6	0.405	38	0.379	5	0.412	8	0.561	62	0.400	4
	2	10	0.396	11	0.399	16	0.391	16	0.919	10	0.963	63	0.639	8
27–30 June	1	81	0.819	87	0.678	62	1.023	41	0.753	80	0.792	351	0.806	72
30 June–4 July	1	160	1.147	163	0.894	176	1.046	175	0.943	142	1.202	816	1.040	161
4–17 July	1	7	0.785	4	0.705	6	0.758	3	1.083	5	0.764	25	0.797	1
	2	7	0.539	2	3.[illegible]30	3	1.300	4	0.438	2	2.330	18	1.152	1
17–23 July	1	13	0.479	9	0.735	14	0.458	15	0.473	14	1.024	65	0.596	6
	2	4	0.969	15	0.894	7	2.042	1	1.250	1	0.330	28	1.184	5
23–28 July	1	70	1.094	61	1.214	54	1.279	47	1.594	67	1.002	299	1.212	103
28–30 July	1	22	0.814	26	1.197	11	0.754	13	0.668	12	0.593	84	0.871	33
30 July–3 August	1	12	0.501	18	0.501	13	0.787	13	0.575	7	0.877	63	0.617	81
	2	3	0.150	6	0.523	9	0.360	8	0.634	3	0.717	29	0.537	32
3–6 August	1	10	0.480	6	0.505	1	1.000	9	0.370	3	1.276	29	0.924	7
	2	2	0.250	9	0.439	4	0.263	8	0.583	12	0.686	35	0.525	5
6–9 August	1	15	0.943	19	0.609	13	0.720	18	0.848	11	0.606	76	0.751	14
9–17 August	1	21	0.647	51	0.796	42	1.548	41	0.530	9	0.895	164	0.913	38

Note. n, sample number; $\Sigma_1 \ldots \Sigma_5$, total fiber count per field of vision; $L\overline{X}_1 \ldots L\overline{X}_5$, mean fiber length (μm) per field of vision; ΣT, total fiber count for 5 fields of vision; $L\overline{X}$: overall average fiber length (μm) for 5 fields of vision. *Values ± 1.

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TABLE 2
SUMMARY OF RELEVANT DATA FOR CALCULATING AMBIENT AIR CONCENTRATION OF FIBERS: ASBESTOS

Sampling period (1980)	n	Σ_1	$L\bar{X}_1$	Σ_2	$L\bar{X}_2$	Σ_3	$L\bar{X}_3$	Σ_4	$L\bar{X}_4$	Σ_5	$L\bar{X}_5$	ΣT	$L\bar{X}$	Fiber concentration (ng m^{-3})[a]
20–23 June	1	41	0.561	29	1.114	29	2.167	37	0.950	32	0.910	168	1.086	48
23–27 June	1	254	1.075	209	2.716	211	1.228	219	1.058	235	1.074	1128	1.402	269
27–30 June	1	229	0.855	210	1.119	83	1.118	126	1.228	125	1.314	773	1.091	205
30 June–4 July	1	30	0.682	3	0.436	8	1.157	25	0.748	18	0.756	84	0.754	12
4 July–12 August	m	m	m	m	m	m	m	m	m	m	m	m	m	m

Note. n, sample number; $\Sigma_1 \ldots \Sigma_5$, total fiber count per field of vision; $L\bar{X}_1 \ldots L\bar{X}_5$, mean fiber length per field of vision; ΣT, total fiber count for 5 fields of vision; $L\bar{X}$, overall average fiber length (μm) for 5 fields of vision; m, missing values. [a]Values ± 1.

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TABLE 3

SUMMARY OF RELEVANT DATA FOR CALCULATING AMBIENT AIR CONCENTRATIONS OF FIBERS: WOTTENVILLE

Sampling period (1980)	n	Σ_1	$L\bar{X}_1$	Σ_2	$L\bar{X}_2$	Σ_3	$L\bar{X}_3$	Σ_4	$L\bar{X}_4$	Σ_5	$L\bar{X}_5$	ΣT	$L\bar{X}$	Fiber concentration (ng m^{-3})*
20–23 June	1	70	0.819	58	0.501	50	0.532	74	0.660	38	0.829	290	0.666	50
23–27 June	1	13	0.821	17	1.762	33	0.578	16	1.267	27	0.812	111	1.041	22
27 June–4 July	m	m	m	m	m	m	m	m	m	m	m	m	m	m
4–17 July	1	46	0.525	28	0.799	32	0.616	24	0.788	24	0.536	154	0.637	22
17–23 July	1	6	2.231	12	1.065	4	0.955	13	0.472	11	1.459	46	1.135	2
23–28 July	1	102	0.350	31	0.845	12	0.412	14	1.047	20	0.733	179	0.535	18
28–30 July	1	12	0.600	17	0.715	17	1.327	11	0.595	11	0.710	68	0.828	129
30 July–3 August	1	30	1.516	54	1.229	36	0.928	30	0.788	20	0.834	170	1.059	36
3–6 August	1	61	1.150	22	0.915	19	0.728	27	0.965	50	0.863	179	0.973	43
6–9 August	1	30	0.421	26	0.494	21	0.340	17	0.952	19	0.546	113	0.524	84
9–12 August	1	25	0.446	22	0.276	19	0.976	15	1.032	19	0.363	100	0.581	15

Note. n, sample number; $\Sigma_1 \ldots \Sigma_5$, total fiber count per field of vision; $L\bar{X}_1 \ldots L\bar{X}_5$, mean fiber length per field of vision; ΣT, total fiber count for 5 fields of vision; $L\bar{X}$, overall average fiber length (μm) for 5 fields of vision; m, missing values. *Values ± 1.

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TABLE 4

DESCRIPTIVE STABILITY CLASSES DERIVED FROM THE STABILITY INDEX (SI)

Range of SI values	Stability class
−1.0 to −0.7	Extremely unstable
−0.5 to −0.4	Moderately unstable
−0.4 to −0.18	Moderately to slightly unstable
−0.17 to −0.13	Slightly unstable
−0.12 to −0.01	Slightly unstable to neutral
0	Neutral
0.01 to 0.03	Neutral to slightly stable
0.03 to 0.05	Slightly stable
0.05 to 0.11	Moderately stable
>0.11	Very stable

When fiber concentrations are related to atmospheric stability and windiness, several interesting relationships become evident. For the station at Danville, which lies to the west-north-west of the mining area, wind direction seems to be critical in determining ambient air fiber concentrations (Fig. 2): winds from the east are associated with highest fiber concentrations, whereas westerly and southerly winds are associated with lowest concentrations. Atmospheric stability also seems to be a factor since lowest concentrations occur under relatively unstable conditions, when mixing is enhanced, and highest concentrations occur under more stable neutral conditions, when vertical mixing is subdued. Examining the values of the ventilation coefficients, their relationship to fiber concentration is less clear (Fig. 3) although it appears that higher fiber concentrations are generally related to higher ventilation coefficients, the latter being the consequence of increased windiness and hence turbidity, which tends to increase the diffusion of fibers to nearby stations. Again, the influence of wind direction seems to be dominant.

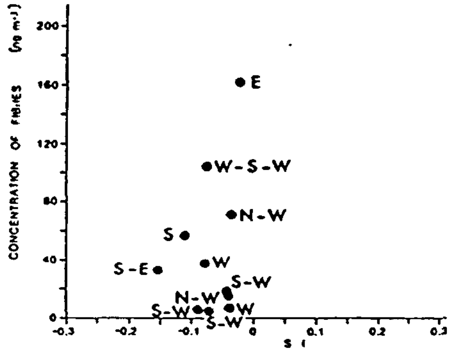

FIG. 2. Fiber concentration, stability index, and wind direction, Danville.

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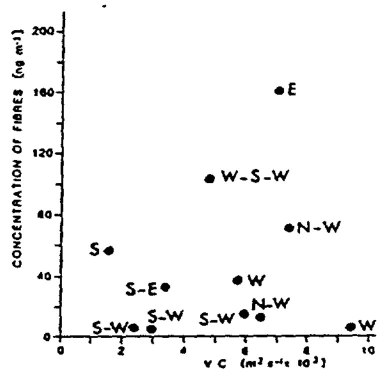

FIG. 3. Fiber concentration, ventilation coefficient, and wind direction, Danville.

For the Asbestos station, which lies to the immediate east of the mining area, it is very evident that wind direction is the dominant factor, with westerly winds being associated with highest fiber concentrations and easterly winds, the reverse (Fig. 4). The influence of atmospheric stability is also evident with highest concentrations occurring under near neutral conditions when diffusion is restricted. These relationships are also evident when considering the ventilation coefficients: *VC* (Fig. 5). In Fig. 5, the influence of wind direction however seems to overrule that of ventilation, although higher ventilation coefficients seem to give rise to

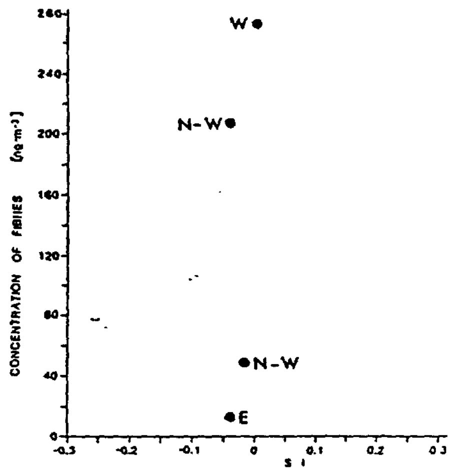

FIG. 4. Fiber concentration, stability index, and wind direction, Asbestos.

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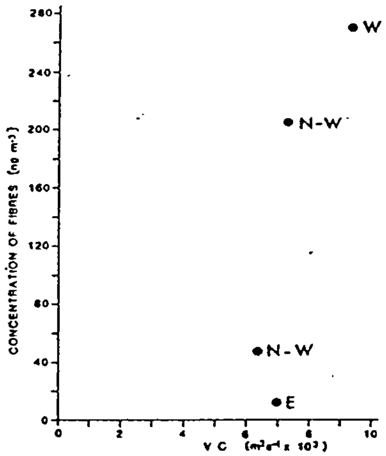

FIG. 5. Fiber concentration, ventilation coefficient, and wind direction, Asbestos.

higher fiber concentrations, this again being most likely due to increased windiness.

For the town of Wottenville, which lies to the east-south-east of the mining area, highest fiber concentrations are not entirely explainable in terms of wind direction. It seems that highest concentrations occur when winds are south-easterly, that is coming from a source region other than the mining area (Fig. 6). The relatively unstable atmospheric condition on this occasion (Fig. 6), however,

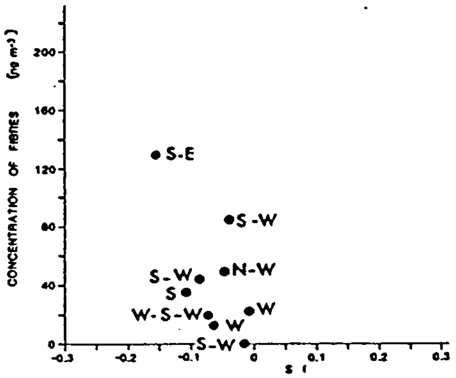

FIG. 6. Fiber concentration, stability index, and wind direction, Wottenville.

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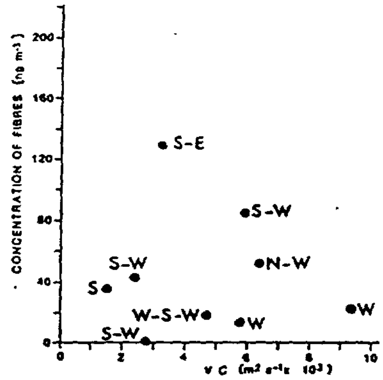

FIG. 7. Fiber concentration, ventilation coefficient, and wind direction, Wottenville.

indicate that diffusion of the fibers is intensified so that wind direction may be a poor indicator of fiber concentration distribution. For this station then, it appears that atmospheric stability (SI) is more critical than wind direction in determining the ambient air concentration of fibers. When examining the influence of the ventilation coefficient *VC* (Fig. 7), its relationship to fiber concentration is not well defined although again, generally, it appears that higher fiber concentrations occur when *VC* is moderately high signifying that increased windiness and mixing allows for a greater diffusion of the fibers away from the mining areas. Also, for the same wind direction, higher fiber concentrations are related to higher *VC* values, this emphasizing the influence of windiness and turbidity.

Putting these various variables and parameters together in Table 5, it is evident, for the time periods when data are available, that highest fiber concentrations occur at Asbestos, this being mainly due to wind direction with respect to the source region and to proximity to the source region. Even these very local concentrations however, as shown previously, seem to be sometimes related to atmospheric diffusion processes. Fiber concentrations at the other stations, especially Wottenville, however seem to be more closely related to atmospheric diffusion than to wind direction. Furthermore, for each station, there exist significant temporal variations in fiber concentration, these being due very likely to the sequence of synoptic events.

CONCLUSION

Because of the paucity of data points, we were unable to carry out exhaustive statistical tests of our hypotheses. However, several conclusions can be drawn from the results of this study. First, it seems that there are large temporal variations in ambient air fiber concentrations in the study regions regardless of site, and that these variations are essentially related to synoptic conditions, mainly windiness and turbulence. Furthermore, for stations located close to the source

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TABLE 5
FIBER CONCENTRATION AND CLIMATIC PARAMETERS

	Fiber concentration (ng m^{-3})			Stability indices			Wind	
	Asbestos	Danville	Wottenville	SI	VC (m^{2}s^{-1} × 10^3)	Pasquil stability category	Speed (m s^{-1})	Direction
June								
20–23	47.845	13.528	50.078	−0.04	6.35	CD	3.87	N-W
23–27	269.302	6.024	21.781	−0.01	9.33	CD–DE	6.83	W
27–30	204.650	71.740	—	−0.04	7.31	CD	4.82	N-W
July								
1–4	12.350	161.361	—	−0.02	6.97	CD	5.47	E
4–17	—	1.221	22.365	—	—	—	—	—
17–23	—	5.129	1.555	−0.07	2.80	C–CD	2.24	S-W
23–28	—	103.331	18.219	−0.08	4.71	C–CD	3.26	S-S-W
28–30	—	33.368	128.515	−0.16	3.22	BC–CD	2.64	S-E
30–3	—	42.639	35.890	−0.11	1.47	C–BC	1.92	S
August								
3–6	—	5.727	43.177	−0.09	2.37	CD	2.29	S-W
6–9	—	14.460	84.407	−0.04	5.91	CD	3.10	S-W
9–12	—	37.960	14.575	−0.07	5.73	CD	3.94	S

Note. Modified Pasquill stability categories: A, Extremely unstable; B, Moderately unstable; BC, Moderately to slightly unstable; C, Slightly unstable; CD, Slightly unstable to neutral; D, Neutral; DE, Neutral to slightly stable; E, Slightly stable; F, Moderately stable; FG, Moderately to extremely stable.

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