Chronic obstructive pulmonary disease in two cities of contrasting air quality

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Summary: Spirometric tests of 3280 Ottawa residents in 1969-71 and 2208 Sudbury residents in 1972-73 showed that the mean ratio of forced vital capacity to forced expiratory volume in 1 second was lower in Sudbury, where sulfur dioxide concentrations in the air tend to be appreciably higher than in Ottawa. This difference was significant for both males and females considered separately, and held true when age and smoking habits were taken into account. The prevalence of symptomatic chronic bronchitis was significantly higher in Sudbury males than in Ottawa males, but no such difference could be detected in females.

Résumé: *Pneumopathie chronique obstructive dans deux villes dont la qualité de l'air est très différente*

Des épreuves spirométriques faites chez 3280 résidents d'Ottawa en 1969-71 et chez 2208 résidents de Sudbury en 1972-73 ont démontré que le rapport moyen entre la capacité vitale forcée et le volume expiratoire forcé dans 1 seconde était plus faible à Sudbury, ville où les concentrations dans l'air de bioxyde de soufre ont tendance à être nettement plus élevées qu'à Ottawa. Cette différence était significative tant chez les hommes que chez les femmes, considérés séparément, et est demeurée vraie quand on prenait en considération l'âge et les habitudes de fumer. La prévalence de la bronchite chronique symptomatique était significativement plus élevée chez les hommes de Sudbury que chez ceux habitant Ottawa, mais cette différence n'a pu être décelée chez les femmes.

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During 1969-71 a household survey for chronic obstructive pulmonary disease, whose objectives and methods have been described elsewhere,[1] was carried out in Ottawa. This was intended as the first of a series to cover a number of Ontario localities between which there were clear differences in the amount or type of air pollution. The second city selected for study, during 1972-73, was Sudbury, seat of the largest nickel and copper smelting operation in the world, which, despite great improvement in recent years, still emits more than twice as much sulfur dioxide (SO_2) daily as does New York City.

According to the provincial Ministry of the Environment, which constantly monitors SO_2 pollution in Sudbury and elsewhere, the official pollution index in Sudbury frequently approached maximum permissible values during the 2 years of the survey and this necessitated shutdown of smelting operations on 22 occasions. Shutdown is required when this index, which is scaled from 1 to 100, reaches 100, corresponding to an average of 0.30 parts per million (ppm) of SO_2 over a 24-hour period, and to approximately 400 $\mu g/m^3$ of suspended particulate matter. On no occasion has the pollution index in Ottawa reached the value at which an industrial shutdown could be ordered. However, because Ottawa has approximately three times the population of Sudbury, the former would be expected to have more atmospheric pollution from domestic and motor vehicle sources, and indeed the average amount of suspended particulate matter for the locations at which measurements were made was appreciably greater in the larger city (Table I).

During the survey periods SO_2 was measured in Sudbury at the Ash Street water tank, at 394 Montague Ave. and at 765 Barry Downe Rd., and in Ottawa at MacDonald Gardens; suspended particulate matter was measured in Sudbury at the Ash Street water tank and at 50 Cedar St.,

Table I—Principal measures of atmospheric pollution, Ottawa and Sudbury, 1971-73*

	Sulfur dioxide† (ppb)	Suspended particulate matter ($\mu g/m^3$)‡
Ottawa	16.1	90.5
Sudbury	32.5	52.1

*Source: air management branch, Ontario Ministry of the Environment, 1974 (personal communication)
†Arithmetic mean of annual arithmetic means.
ppb = parts per billion
‡Geometric mean of annual geometric means.

and in Ottawa at MacDonald Gardens, and at the Kenton Building and the Ottawa Electric Building, both on Bank Street.

It is not claimed that these measurements precisely characterize the intensity of exposure of Sudbury and Ottawa residents to pollutants; indeed this has not been convincingly achieved for any general population group. However, the main points are clear: Sudbury air contains more SO_2 and less suspended particulate matter than Ottawa air.

In terms of economic status, as indicated by median family income, these two cities are similar and somewhat above the general Ontario level (Table II). Another socioeconomic indicator is educational achievement: Ottawa has a higher percentage of residents with postelementary education than does Sudbury or the province as a whole.

Methods

Collection of data

Samples of 1869 households in Ottawa and 1235 households in Sudbury were chosen by a three-stage probability process, in which streets were selected, then blockfaces within streets, and then three households within each blockface together with alternatives to be used only if the selected houses were found to be vacant or demolished. All persons over 14 years of age in the selected households were to be included in the survey, for a total target group of 3631 individuals in Ottawa (1863 males and 1948 females) and 2421 in Sudbury (1198 males and 1223 females).

The main components of the survey were a spirometric test and administration of the British Medical Research Council (MRC) questionnaire on respiratory symptoms (abbreviated form),[2] with additional questions on residence history and smoking habits. To balance any effects of seasonal variation we conducted both surveys continuously throughout the years indicated, with the exception, in both communities, of the months of January and February, which are the coldest and least suitable for interviewing. The overall response of all households was satisfactory, with a completion rate of more than 90%; the final samples included 3280 Ottawa residents and 2208 Sudbury residents. The only difference in the conduct of the surveys in the two cities was that in Ottawa we employed two groups of interviewers — a group of lay volunteers and a group of nurses undergoing public health training; in Sudbury all fieldwork was done by paid lay interviewers. This choice was made after experience in Ottawa had shown that there was no difference in the answers obtained by each type of interviewer but that the refusal rate was higher for the volunteers. The refusal rate for the paid interviewers in Sudbury was 3.8%, compared with 16.2% for the volunteers in Ottawa.

Selected interviewers were specially trained to use McKesson Vitalor spirometers in the field. All tracings were reviewed and interpreted in the home office, where the best of three tracings was selected and used to obtain observed and expected values for forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1).

Analysis of data

The survey data were analysed in terms of FVC and FEV_1 considered separately, and in terms of the widely used ratio FEV_1/FVC. Because all three analyses showed similar trends, for this report we used only the ratio FEV_1/FVC, which does not require adjustment for height and permits comparison with most other published data. A possible disadvantage is that, because the McKesson Vitalor has a limited capacity of 4.8 *l*, the superiority of individuals with a large FVC may be overestimated. Such bias would mainly affect results for younger age groups, since few older subjects have an FVC greater than 4.8 *l*. In our survey FVCs of 4.8 *l* or more were found in only 52 subjects in Ottawa (1.6%) and 25 subjects in Sudbury (1.1%).

Respondents were classified into one of three groups according to smoking history: never smoked, exsmoker and current smoker. Then current smokers were subdivided into three classes of cigarette smokers — less than 10 cigarettes, 10 cigarettes to 1 pack, and more than 1 pack per day — and a mixed class of cigar and pipe smokers.

Male respondents were placed in one of three occupational categories: employment at any time in smelting, mining or quarrying (corresponding to items 39 to 42 of the MRC questionnaire); employment in pottery works, cotton, flax or hemp mills, asbestos mining or milling, or any other "dusty occupation" (items 43 to 46 of the MRC questionnaire); and other occupations.

The survey data were analysed on the basis of several definitions of chronic bronchitis.[3-7] Absolute prevalence rates vary substantially according to the restrictiveness of the criteria, but the patterns of prevalence variation are broadly consistent. The definition of chronic bronchitis used in this report is that of Fletcher and colleagues[3] — persistent cough and production of phlegm. Because this definition makes no reference to spirometry there is no built-in agreement between the findings for respiratory function and those for prevalence of symptomatic disease, which rely on subjective reporting.

Subjects were initially classified into four main age groups (14 to 24, 25 to 44, 45 to 64, and 65 years or over) but we considered only the first three groups for this report because the prevalence of respiratory impairment increases rapidly with age after 65, so that it is desirable to have either a good initial match in age distribution between the samples to be compared or an effective standardization for age. There was not, in this one age group, a satisfactory match between the Ottawa and Sudbury samples, and the small numbers of subjects prevented effective standardization.

To ensure that the geographic comparisons would be as valid as possible, we first divided the residents of each city into 36 primary groups derived from the complete three-way classification by sex, age and the six smoking categories. There were found to be too few females for statistical analysis in the mixed category of pipe and cigar smokers; this reduced the number of primary groups to 33. Further exclusions were males in the mixed category of pipe and cigar smokers (three groups) and exsmokers of both sexes (six groups), none of which could be confidently located on the continuum of increasing exposure — that is, from nonsmokers to current smokers of 25 or more cigarettes per day.

Table II—Characteristics of residents of Ottawa and Sudbury, compared with those in all Ontario

Characteristic	Ottawa	Sudbury	All Ontario
Median total annual family income, $	11 127	11 115	10 661
% of population > 5 years old and not attending school with grade 9 education or higher	75.3	61.1	65.8
% of population originating (by descent) from British Isles/France/other countries*	55/25/20	37/32/31	59/10/31
% of males ever employed in†			
Smelting, mining or quarrying	6	35	—
Certain dusty occupations‡	17	23	—
Remainder	77	42	—

*1971 census data.
†Data of present survey.
‡Pottery works, cotton, flax or hemp mills, asbestos mining or milling, etc.

In calculating mean values each primary cell in Tables III and IV was given equal weight; hence the comparison values represented by the italicized figures were effectively standardized for the relatively minor differences between the Sudbury and Ottawa samples in distribution by age and by smoking habits. Error variances for overall comparisons were estimated by adding 12 separately computed error variances (one for each primary cell of age x smoking) and dividing the sum by 144 (12^2).

Results

FEV_1/FVC ratios

The overall mean FEV_1/FVC ratio was 0.856 for subjects aged 14 to 24 years, declining to 0.809 at ages 25 to 44 and to 0.792 at ages 45 to 64 (Table III). Each sex also showed a decline in ratio with increasing cigarette smoking, most of the difference being between the nonsmokers and those smoking least heavily. In both cities males showed slightly lower ratios than females of similar age and smoking habits. Within each sex Sudbury residents showed lower mean ratios than Ottawa residents, the margins of difference being as follows:

Males: 0.7933 − 0.8263 = − 0.0330; standard error, ± 0.00981 (Z = − 3.36; P < 0.001).

Females: 0.8080 − 0.8446 = − 0.0366; standard error, ± 0.00860 (Z = − 4.25; P < 0.001).

The overall estimated difference increased with age, considering the two sexes together, from 0.017 at ages 14 to 24 to 0.047 at ages 45 to 64. This is consistent with progressive impairment during prolonged exposure to atmospheric pollutants and is a pattern different from the one to have been expected if the limited capacity of the McKesson Vitalor were an important influence on the findings.

Of the nine primary groups of subjects excluded from Table III and from the above comparisons, seven showed lower mean FEV_1/FVC ratios in Sudbury than in Ottawa.

The difference in mean FEV_1/FVC ratio between these two cities of contrasting air quality was thus ascertained to be highly significant, in the direction expected, and of a magnitude comparable with, though smaller than, the apparent effects of age and of cigarette smoking.

Prevalence of symptomatic disease

The overall prevalence of chronic bronchitis was 50/1000 subjects aged 14 to 24 years, increasing to 90/1000 at

Table III—Mean FEV_1FVC ratios* for samples of residents of Sudbury (S) and Ottawa (O), by sex, age and smoking habits

Age (yr)		Males					Females					Both sexes	
	No. of cigarettes smoked /d	0	1-9	10-24	25 +	Mean	0	1-9	10-24	25 +	Mean	Mean	
14-24	S	0.866	0.824	0.859	0.845	0.849	0.877	0.872	0.857	0.772	0.845	0.847	0.856
	O	0.888	0.869	0.875	0.795	0.857	0.886	0.870	0.842	0.885	0.871	0.864	
25-44	S	0.833	0.783	0.748	0.757	0.780	0.818	0.772	0.794	0.800	0.796	0.788	0.809
	O	0.870	0 848	0.799	0.806	0.831	0.848	0.820	0.838	0.796	0.826	0.829	
45-64	S	0.815	0.726	0.741	0.723	0.751	0.804	0.755	0.783	0.792	0.784	0.768	0.792
	O	0.829	0.774	0.781	0.781	0.791	0.848	0.830	0.832	0.840	0.838	0.815	
All ages	S	0.838	0.778	0.783	0.775	*0.793*	0.833	0.800	0.811	0.788	*0.808*	*0.801*	
	O	0.862	0.830	0.818	0.794	*0.826*	0.861	0.840	0.837	0.840	*0.845*	*0.836*	
Both cities		0.850	0.804	0.801	0.785	*0.810*	0.847	0.820	0.824	0.814	*0.826*	*0.818*	

*Italicized figures represent overall mean ratios, with age and smoking habits considered simultaneously.

Table IV—Prevalence* of chronic bronchitis (per 1000) for samples of residents of Sudbury (S) and Ottawa (O), by sex, age and smoking habits

Age (yr)		Males					Females					Both sexes	
	No. of cigarettes smoked/d	0	1-9	10-24	25 +	Mean	0	1-9	10-24	25 +	Mean	Mean	
14-24	S	49	49	47	118	63	15	22	68	91	49	56	50
	O	4	0	37	52	23	16	54	87	91	62	43	
25-44	S	62	103	43	170	95	33	87	86	130	84	90	90
	O	10	49	83	245	97	20	32	70	209	83	90	
45-64	S	59	222	247	179	177	27	74	102	238	110	144	120
	O	13	0	133	235	95	39	43	86	229	99	97	
All ages	S	57	125	112	156	*112*	25	61	85	153	*81*	*97*	
	O	9	16	84	177	*72*	25	43	81	176	*81*	*77*	
Both cities		33	71	98	167	*92*	25	52	83	165	*81*	*87*	

*Italicized figures represent overall mean ratios, with age and smoking habits considered simultaneously.

ages 25 to 44 and to 120/1000 at ages 45 to 64 (Table IV). Each sex showed an overall increase of fivefold or greater in reported disease prevalence with increasing cigarette smoking. More males reported chronic bronchitis on the average than did females of similar age and smoking habits (92/1000 v. 81/1000); this reflects the pronounced excess of males with chronic bronchitis in Sudbury (112/1000 v. 81/1000). In Ottawa the prevalence was marginally lower for males.

The overall prevalence, considering the two sexes together, was higher, as expected, in Sudbury (97/1000 v. 77/1000). This is the result of a significant excess in Sudbury males. The prevalence rates for females of the two cities were indistinguishable. The margins of difference were as follows:

Males: 112 − 72 = + 40/1000; standard error, ± 18 ($Z = + 2.2$; $P \approx 0.03$).

Females: 81 − 81 = 0/1000; standard error, ± 19 ($Z = 0.0$; $P > 0.9$).

Of the six primary groups of males excluded from Table IV and from the above comparisons, five showed a higher prevalence in Sudbury (average margin, 68/1000). Of the three groups of females excluded, two showed a higher prevalence in Sudbury, but the average margin of 4 was in Sudbury's favour.

The difference in disease prevalence between these two cities was thus ascertained to be significant and in the expected direction only for males, the females showing no detectable difference in prevalence of symptomatic illness despite the measured difference in respiratory function.

The overall geographic difference in disease prevalence among males is of a magnitude comparable with the differences between successive age groups but is much weaker than the apparent effect of smoking.

It has been suggested that air pollution and smoking may have a synergistic effect on the incidence of lung cancer[8] and bronchitis.[9] In the present data no significant interaction could be detected.

Discussion

This study has several features in common with a two-city study reported a decade ago, in which Chilliwack, BC (taken as an example of a community free from air pollution) was compared with Berlin, New Hampshire (where both SO_2 and dustfall were regarded as problems).[10] In each of these studies cigarette smoking was found to be the dominant influence on disease frequency, and lung function was significantly poorer in residents of the more polluted area. However, prevalence of symptomatic disease was judged not to differ between Chilliwack and Berlin (after due allowance had been made for differences in smoking), as was the case for residents of Ottawa and Sudbury.

This raises the question whether the higher rate of symptomatic disease in Sudbury males may be at least partly attributable to occupational factors rather than to the general level of air pollution. Within the Sudbury sample the prevalence of bronchitis was higher among males who had worked in smelting or mining than among those who had worked in other dusty occupations; the latter, in turn, had a higher prevalence than the remainder of the sample. However, these differences were not significant. More evidence concerning possible occupational effects in Sudbury should emerge from data now being analysed by the Ontario Ministry of Health (J.E. Cowle,* J.A. Budlovsky: personal communication, 1974) by means of a finer breakdown than is provided by the MRC classifications referred to above, in which subgroups have been defined on the basis of occupational exposure to sulfur dioxide. Sudbury was chosen for comparison with Ottawa because of the known difference in air pollution. Having verified that the residents of these two cities differ measurably in respiratory function and in prevalence of chronic bronchitis, we must now consider whether this difference could be explained by factors other than air pollution. Three classes of explanatory factors have been suggested,† none of which appears to us to be a serious rival to air pollution exposure.

First is the question of ethnic origin. These two cities have, in fact, a broadly similar composition with respect to national origin (Table II) and, compared with the province as a whole, both have a relatively high proportion of persons of French descent. First-generation immigrants to Ontario from outside Canada (of whom there may be more in the Sudbury population) do have higher death rates from respiratory disease than the native-born, but this is believed to be explicable in terms of differences in smoking habits, for which the comparisons made in the present study were fully standardized. It has also been suggested that racial differences in FVC may exist on the basis of differences in mean stature, but the use of the FEV_1/FVC ratio should control any bias of this type.

Second, climate may have an influence. However, the two cities, both with a typical continental climate, are at approximately the same latitude, in a region where the isopleths run east to west. They are therefore in the same zone with respect to temperature, humidity, barometric pressure and precipitation.

Third, these studies were not conducted simultaneously. Because of the increasing incidence of chronic respiratory disease, prevalence rates for any later period might tend to exceed those of any earlier period and this may have biased the comparison to the disadvantage of Sudbury. However, the interval was only 2½ years, so that any bias in the estimate of crude prevalence would be small. Bias in rates standardized for age and smoking habits would be smaller still.

We acknowledge, however, that the comparison between these two cities might give an exaggerated impression of the effect of air pollution on health if only recent exposure data were considered. It is more likely that the respiratory differences noted in this study developed over an extended period, during most of which the contrast in air quality was much harsher than it is today.

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