Respiratory Symptoms and Air Pollution Changes in Children: The Gardanne Coal-Basin Study

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ABSTRACT. The influence of daily changes in sulfur dioxide (SO_2) levels on the induction of respiratory symptoms was studied during the 1983–1984 winter in 450 children, aged 9 to 11 yr, living in the Gardanne coal-basin, France. In this area, SO_2 originates mainly from a coal-fueled power plant. The mean SO_2 level during the winter was 22 $\mu g/m^3$ in low-pollution areas and 93 $\mu g/m^3$ in polluted areas, with daily SO_2 levels up to 356 $\mu g/m^3$. Children completed a daily diary about respiratory symptoms. In the polluted communities only we demonstrated a significant association between daily SO_2 levels (after controlling for temperature and respirable particle variations) and prevalence of upper and lower respiratory symptoms. However, in each polluted town, and for each respiratory symptom, there was no evidence for either a latency period or a delay in the effects of pollutants. Mean daily temperature was also closely correlated with upper and lower respiratory symptoms in most of the polluted and some low-pollution communities. In a second step, the prevalence of respiratory symptoms in each town was compared, during two 2-wk periods, with air pollution levels; higher prevalences were found during the pollution period. In conclusion, moderate daily changes in SO_2 levels induce a significant but transient increase in the prevalence of respiratory symptoms in children.

THE MEUSE VALLEY (1930), Donora (1948), London (1952, 1956, 1962), and New York (1953, 1966) are prime examples of acute air pollution episodes leading to increased mortality and morbidity. Subsequently, mean air pollution levels have gradually decreased to comply with official standards. The evaluation of adverse health effects of exposure to relatively low levels of regulated air pollutants is now of major concern. Recently, an extension of the industrial facilities of the Gardanne coal power plant, near Marseille, France, was implemented. The extension included a new facility that generated 600 megawatts (MW) and became operative in November 1984. Health effects of air pollution were evaluated before and after the starting of this generation. From December 1983 to March 1984, we performed baseline studies and evaluated

short- and long-term effects of air pollutants. In this paper, we will report the evaluation of daily changes in sulfur dioxide (SO_2) levels on the induction of respiratory symptoms in children.

Materials and methods

The Gardanne coal-basin comprises an area of approximately 650 km² (Fig. 1). It is surrounded on its northern and southern bounds by two mountain ranges: Montagne de Sainte-Victoire, Chaîne de l'Etoile, and Montagne de Regagnas, respectively. Gardanne, the main town, has 17,000 inhabitants. A coal mine has been operating there since the 17th century. The annual coal production is approximately 1.6 million metric tons. To be profitable, the coal must be burned on site. In 1983–1984, three power plants operated, totaling 350 MW, and released 420 metric tons of SO_2 daily in the air through chimneys 125 m high. The coal company provides miners with free coal for domestic use. The annual domestic consumption is approximately equal to 2,600 metric tons. The air pollution in this area has two characteristics: (1) it has been unevenly distributed, with some polluted areas having a mean SO_2 level of 93 $\mu g/m^3$ during the 1983–1984 winter and some low polluted areas having a mean level of 22 $\mu g/m^3$. Air pollution is composed predominantly of SO_2, as the coal has a 3.5% sulfur content, which is the largest percentage in France.

The study included 450 primary schoolchildren from the third, fourth, and fifth grades who lived in eight communities of the Gardanne coal-basin (Fig. 1): five polluted communities (Gardanne, Biver, Meyreuil, Bouc, and Greasque), and three low-pollution communities (Trets, Luynes, and Rousset).

In each community, all children attending the third, fourth, and fifth grades were enrolled in the study. Children were chosen because they do not smoke, are not exposed to occupational hazards, and spend the entire day in an homogeneous air environment.

Methods

Respiratory symptoms were reported in a daily diary that was provided by the teacher on Saturday morning

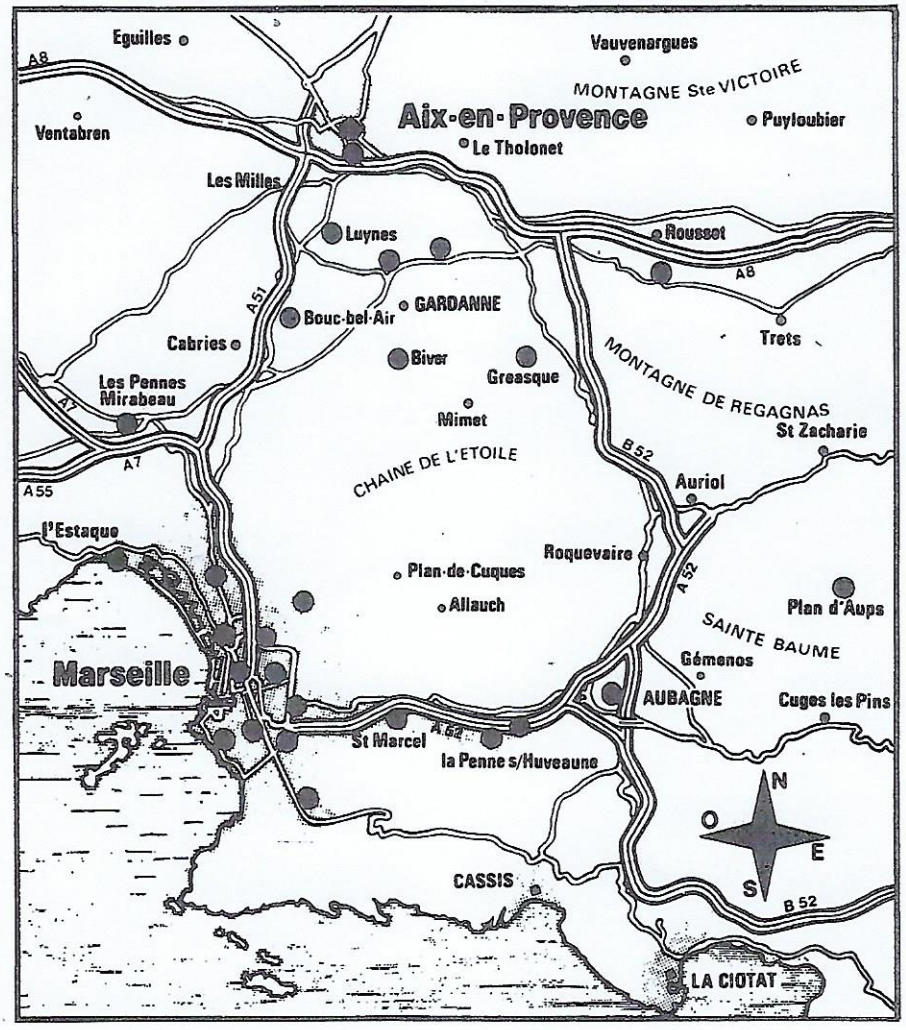


Fig. 1. Location of the Gardanne coal-basin, between the towns of Marseille and Aix-en-Provence. The *black dots* represent the sites of the air pollution monitoring stations.

and collected the following Saturday. Parents were asked to monitor the completion of the diary. Teachers, when collecting the diaries, perused them and clarified issues when necessary. The following questions were answered daily: "Today had you: a morning cough, eye irritation, a runny nose, any sneezing, sore throat, wheezing in the chest, fever? Have you missed the class? Have you been out of town?" (Symptoms such as eye irritation, runny nose, and sneezing have been considered together under the heading "E.N.T. symptoms," and morning cough and wheezing in the chest appear as "pulmonary symptoms."

The Aix-Marseille air pollution monitoring department measured, on a 15-min sampling basis, two major pollutants: (1) SO_2, with an automatic analyzer (AF 20), using an ultraviolet fluorescence technique and (2) respirable particles, MPSI 100, Environment SA, Poissy, France, using a β-gauge. Of the children enrolled in this study, 95% lived within 2 km of the schools and air pollution stations.

In Table 1 are listed, for each community, the monthly mean levels of the two major pollutants and minimum and maximum daily levels. Nitrogen oxides (NO) have not been considered as their level was very low and stable in this area (for example, in Gardanne, the most polluted community, the NO level in January 1984 was equal to 17 $\mu g/m^3$ [maximum daily level = 30 $\mu g/m^3$]).

The statistical analysis involved computing partial correlation coefficients between daily prevalence of each symptom and daily mean level of air pollutants or daily respirable particle level. Indeed, daily temperature variations and daily respirable particle levels may act as confounding factors in the relationship between variations in SO_2 level and daily symptoms. To evaluate a latency period or a delay in the effect of the pollutants, we used a time-series analysis. To compare the prevalence rates of symptoms during two different periods, we used a chi-square test.

Results

Correlation between daily air pollutant levels and daily mean prevalence of respiratory symptoms. In the most polluted communities—Biver and Gardanne—there was a statistically significant association (Table 2) between daily SO_2 levels and prevalence of morning cough and wheezing in the chest. Moreover, there was a correlation between mean SO_2 level and prevalence of eye irritations in children from Gardanne and prevalence of runny nose in children from Biver. These correlations were demonstrated in January and February 1984. In December 1983 and March 1984 there were data missing due to school holidays. Absence from school was not correlated with daily SO_2 level. The daily prevalence of pulmonary, as well as ENT symptoms in Gardanne, was significantly correlated with daily SO_2 levels. In contrast, there was no correlation between daily prevelance of symptoms and daily respirable particle levels. After accounting for respirable particle variations, the correlation coefficients listed on Table 2 exhibited very minute variations.

In low-pollution communities there was no relationship between the levels of any of the two major pollutants studied and the daily prevalence of respiratory symptoms. The time-series analysis showed that there was no latency period, i.e., the association between air pollution levels and daily symptoms did not show up 1, 2, or several days after an episode of high air pollution. When a correlation was demonstrated on a daily basis, it did not last for the following days.

After accounting for the effect of SO_2, variations in daily mean temperature showed a statistical association with prevalence of ENT or pulmonary symptoms in most of the polluted communities but also in some low-pollution communities (Table 3). Prevalence of wheez-

Table 1.—Monthly Mean Values for Sulfur Dioxide (SO_2) and Respirable Particles (RP), during the Course of the Study (December 1983 to March 1984), in Each Community

	Polluted community ($\mu g/m^3$)				Low pollution community ($\mu g/m^3$)		
	Gardanne*	Meyreuil	Bouc	Greasque	Trets	Luynes	Rousset
December 1983							
SO_2	156(19–302)†	76(0–159)	124(10–502)	72(10–360)	26(0– 85)	25(2– 56)	30(8–101)
RP	46(21–125)	60(22–112)			75(49–124)	79(26–262)	
January 1984							
SO_2	146(49–229)	98(32–173)	83(11–226)	65(23–140)	21(8– 44)	18(9– 36)	18(3–30)
RP	56(27– 90)	52(32– 83)		43(36– 55)	60(28–109)	71(31–111)	
February 1984							
SO_2	143(27–214)	79(8–135)	70(12–211)	23(6– 45)	14(0– 28)	14(0– 28)	14(3–31)
RP	83(49–138)	74(27–120)		55(35–104)	92(49–143)	88(41–112)	
March 1984							
SO_2	84(24–228)	81(9–144)	47(8–157)	55(9–375)	27(11– 56)	19(4– 51)	24(9–47)
RP	82(49–117)	74(33–144)		70(39–126)	86(43–125)	69(38–123)	

*A neighboring community, Biver, is exposed to the same levels of air pollutants that prevail in Gardanne.
†Minimum and maximum daily levels are indicated within parentheses.

Table 2.—Partial Correlation Coefficients between Daily Mean Symptom Score in Each Community and Daily SO_2 Level

Town	Mean SO_2 in January 1984 ($\mu g/m^3$)	Cough	Eye irritations	Runny nose	Sneezing	Wheezing	Symptoms	
							ENT	Pulmonary
Gardanne	146	0.24*	0.26*	0.14	0.20	0.54†	0.36†	0.26*
Biver	146	0.29*	0.16	0.25*	0.22	0.44†	0.03	0.31*
Meyreuil	98	−0.12	−0.03	−0.09	−0.08	0.17	−0.08	−0.10
Bouc	83	−0.17	−0.11	−0.08	−0.14	−0.23	−0.13	−0.18
Gréasque	65	0.21	0.14	0.20	0.23	0.23	0.03	0.22
Trets	21	0.06	−0.01	0.05	0.08	0.12	0.05	0.07
Luynes	18	0.08	0.19	0.15	0.08	–	0.12	0.08
Rousset	21	−0.10	−0.18	0.13	0.03	0.19	0.03	0.07

Note: Data used are from January 1984, the month of greatest pollution levels during the course of the study.
*$p < .05$.
†$p < .01$.

Table 3.—Partial Correlation Coefficients between Daily Mean Temperature and Respiratory Symptoms

Town	Cough	Eye irritations	Runny nose	Sneezing	Wheezing	Symptoms	
						ENT	Pulmonary
Gardanne	−0.17	−0.22	−0.22	−0.19	0.14	−0.05	−0.15
Biver	−0.34†	−0.53†	−0.16	−0.27*	−0.04	−0.36†	−0.32†
Meyreuil	−0.29*	−0.25*	−0.31†	−0.30*	0.16	−0.30*	−0.28*
Bouc	−0.25*	−0.50†	−0.38†	−0.36†	−0.14	−0.21	−0.26*
Gréasque	−0.31†	−0.47†	−0.37†	−0.38†	−0.31†	−0.45†	−0.33†
Trets	−0.39†	−0.47†	−0.31†	−0.39†	−0.07	−0.34†	−0.37†
Luynes	−0.09	−0.01	−0.15	−0.02	–	−0.06	−0.09
Rousset	−0.29*	−0.10	−0.21	−0.36†	−0.19	−0.14	−0.29*

*$p < .05$.
†$p < .01$.

ing was related to mean SO_2 levels, not to daily mean temperature.

Comparison of prevalence of respiratory symptoms during two 2-wk periods with contrasted air pollution levels (Table 4). In each community, the prevalence of ENT or pulmonary symptoms was higher, although not significantly, during the polluted period. When data from all communities were pooled, the differences in prevalence rates were statistically significant for ENT ($p < .05$) and pulmonary symptoms ($p < .02$). Of note is that mean daily temperature and humidity were comparable during the two 2-wk periods.

Discussion

In this study, moderate daily changes in SO_2 levels induced a significant but transient increase in the prevalence of respiratory symptoms in children. Mean daily temperature was also closely correlated with upper- and lower-respiratory symptoms. In contrast, there was no association between daily symptoms and daily respirable particle levels. Such a lack of association has also been demonstrated in children of the PAARC study.[1] We chose to study children because they are not directly exposed to potential confounding factors such as smoking and occupational hazards and usually do not migrate. Also, the children's atmospheric environments can be fairly precisely defined for most of their lives by the conditions in the area in which they live.

In the literature, air pollution effects have been studied mainly through examination of pulmonary function tests. The association between air pollution and respiratory symptoms has been studied less extensively in sensitive subjects, e.g., children or asthmatic or bronchitic patients. Douglas and Waller[2] showed that the frequency and severity of lower respiratory tract infections in children increased with the amount of air pollution ranging, as an annual mean, from 90–257 $\mu g/m^3$. Lunn et al.[3] demonstrated a higher incidence of chronic upper respiratory infection in children living in polluted areas (mean SO_2 levels ranging from 194–304 $\mu g/m^3$). As air quality improved, the frequency of respiratory infections decreased.[4] Colley and Reid[5] also found an association between air pollution levels and the occurrence of lower respiratory tract infections in children. In Chicago, in 1963–1964, Burrows et al.[6] could not establish any relationship between high air pollution levels and respiratory symptoms in a group of patients with chronic bronchitis and emphysema. In contrast, Carnow et al.[7] in the Chicago Air Pollution

Table 4.—Mean Prevalence of ENT and Pulmonary Symptoms During Two 2-wk Periods with Contrasted Air Pollution Level

Town	Mean 2-wk SO_2 levels ($\mu g/m^3$)	Mean prevalence of ENT symptoms	Mean prevalence of pulmonary symptoms
Biver	LP: 69	29	17
	P: 147	37	24
Gardanne	LP: 59	45	22
	P: 132	57	31
Bouc	LP: 33	29	14
	P: 116	41	33
Meyreuil	LP: 67	31	14
	P: 120	52	25
Gréasque	LP: 58	41	19
	P: 92	46	27

Notes: Each 2-wk data were totaled for a given symptom at each school and expressed as a percentage of the total reporting children. On the left side of the Table are listed the mean SO_2 level during the 2-wk low-pollution period (LP) and the 2-wk pollution period (P). The communities listed are the polluted communities in which air pollution variations have been large.

Study, showed that elderly bronchitics experienced an exacerbation of symptoms and acute respiratory illness at high daily SO_2 levels. In a group of asthmatic patients, living in a vicinity of a coal-fueled power plant, Cohen et al.[8] observed a significant increase in asthma attacks when 24-hr SO_2 levels reached 220 $\mu g/m^3$. It should be noted that air pollution concentrations reported in these early studies were much higher than those currently prevailing in Western countries. The evaluation of adverse health effects of exposure to low air pollutants is now of major concern.

Few studies have examined the correlation between air pollution changes and daily symptoms. These studies have not carefully monitored the air quality to which the population was exposed. A noticeable exception is Mostardi et al.'s[9] study, which correlated daily 24-hr air pollutants (SO_2, NO_2) levels and daily diaries in a population in Akron, Ohio. The mean SO_2 level during the school year was equal to 77.5 $\mu g/m^3$ in polluted areas and 21.4 $\mu g/m^3$ in low-pollution areas. The incidence of respiratory symptoms, especially cough, runny nose, and sore throat was higher in the polluted area. However, the authors did not perform a statistical analysis to relate daily changes in air pollution and daily symptoms. Such analyses were performed by Lawther et al.[10] in chronic bronchitic patients, using a simple diary technique. They showed that changes in their clinical conditions were closely related to air pollution, as indicated by daily mean concentrations of smoke around 250 $\mu g/m^3$ and sulfur dioxide around 500 $\mu g/m^3$.

More studies in the literature are devoted to short-term effects of air pollution changes on children's pulmonary function. Three studies[11-13] provided negative results; however, high monthly SO_2 levels, i.e., up to 910 $\mu g/m^3$, were reported in Mandi's study.[14] Two studies[12,13] demonstrated a small (2 to 5%) but significant decrease in forced expiratory volume in 1 sec ($FEV_{1.0}$) following high air pollution episodes. Noteworthy, in the Dockery et al.[15] study, the lowest mean $FEV_{0.75}$ values were observed immediately following the alert, while the lowest mean forced vital capacity (FVC) values were observed 1–2 wk after the episodes. Thus, in children there is a discrepancy between the effects of air pollution episodes on respiratory symptoms, which can be demonstrated at moderate SO_2 levels, and effects on pulmonary function, which are, if any, small, even after episodes of high air pollution. It is conceivable that respiratory symptoms following air pollution episodes may not represent an adverse health effect but could be part of an adaptative process. However, there is evidence that a history of repeated, acute, lower respiratory illnesses in childhood may be associated with the development of chronic bronchitis in later life.[16] Longitudinal epidemiological studies are needed to further clarify this issue.

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