

Trend of Air Pollution and its Effect on Human Health in Hiroshima Prefecture

—A Retrospective Study in the Cities of Otake, Kure, Mihara, Takehara,
Fukuyama and Kaita Town, 1977–1992—

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ABSTRACT

The evaluation of adverse health effects resulting from exposure to relatively low levels of ambient air pollution is currently a major concern. By using methodology that directly addressed the time series nature of data, this study investigated the association between ambient air pollution and respiratory symptoms and eye, nose, throat irritation symptoms. Health effects were determined by using the air quality data from ambient monitoring stations located within the Hiroshima Prefecture area. The air pollution data chosen for this study were the mean of annual average concentrations of sulfur dioxide (SO₂), nitrogen dioxide (NO₂), suspended particulate matter (SPM) and photochemical oxidants (O_x). The health data were extracted from the Hiroshima Community Health Study conducted in the cities of Otake, Kure, Takehara, Mihara, Fukuyama and Kaita Town during 1977–1992. The Community Health Study data were obtained by using a Japanese translation of the British Medical Research Council (BMRC) Questionnaire. The analysis was limited to the investigation of the health symptoms reported by subjects and the mean annual average concentrations of ambient air pollution in each study area. The results indicated a significant association between SO₂ levels and lacrimacy symptoms ($p < 0.05$), runny nose ($p < 0.05$) and cough symptoms ($p < 0.05$). This study also found a significant association between O_x and phlegm symptoms reported by the subjects ($p < 0.01$). In contrast, the results found that there was a negative correlation between NO₂ levels and phlegm symptoms reported by subjects. In conclusion, moderate annual changes in SO₂ and O_x levels induce a significant increase of health symptoms in the local community.

Key words: *Ambient air pollution, BMRC questionnaire, Health symptom*

Air pollution is one of the greatest risks to human health and the environment. Air pollution occurs where the natural composition of the atmosphere is altered significantly in a way that is perceived as being harmful. The generation of energy by burning fossil fuels in power stations and automobiles, all manner of industrial processes, biodegradation of wastes, and some farming operations lead to the release of thousands of different chemicals into the air. For many years there has been concern about the effects of this pollution. However, in recent years it has become clear that there are pollutants from an enormous number of sources that cause more an intractable concern. Air pollutants may cause adverse effects on human health.

Many studies have found that there is a higher rate of respiratory diseases among those exposed to high levels of pollutants^{1-4,6,23,26,28-30}. During periods when pollution reaches high levels, many people complain of headaches, irritation of the

eyes, nose and throat, nausea, and a general feeling of ill health. Acid particles, particularly sulfuric acid, correlate most closely with an increase in asthma attacks, and other respiratory symptoms. A high level of particulate matter over prolonged periods correlates with respiratory disease and lung cancer. However, all factors may contribute to various degrees. Most air pollution comes from stationary sources, such as factories, power plants and offices; from mobile sources, including cars, buses and trucks, and from natural sources, such as dust winds.

In Japan, a deterioration in the environment became clear in the mid-1960s. Air pollution caused by nitrogen oxides has worsened as a result of the vigorous activity centered in the cities since the economic boom of this country. Various data released every year show that the environment in Japan is deteriorating more rapidly than in the past. Although the specific problems may differ from those of the 1960s, it is undeniable

that their negative impact upon the environment is the same⁵⁾. Air pollution in this country has produced a long list of health problems, such as chronic bronchitis, bronchial asthma and other respiratory symptoms^{31,32)}.

In order to prevent air pollution, the government has established the Air Pollution Control Law or the Hiroshima Prefecture Pollution Control Ordinance, which requires that the concentration of air pollutants from soot and smoke emitting facilities remains under the regulated exhaust standard. To examine air pollution conditions and to maintain a better living environment, the prefecture and the cities established a system called the Air Pollution Monitoring Telemeter System in 1971. Ambient Air Pollution Monitoring Stations measure the conditions of air pollution for 24 hours and send the information to the monitoring center through radio communications. These monitoring stations with their warning systems may reduce the negative impact of air pollution from factories and industrial areas. The Japanese government has also determined the Environmental Quality Standard (EQS) as the standard that should be maintained for the protection of human health and the preservation of the living environment. However, environmental problems have become an urgent issue as one of the consequences of modern society. The evaluation of the adverse health effects of exposure to relatively low levels of regulated air pollutants is now of major concern.

Although many health effects of environmental pollution remain controversial, epidemiological and clinical research have identified some effects that should be considered by physicians and oth-

er health care providers. Air pollution exposure can cause irritation of the mucous membrane and produce measurable changes in a variety of pulmonary functions such as respiratory mechanics, pulmonary gas exchange, mucociliary and alveolar particle clearance, and airway permeability. This study was intended to document the trends of ambient air pollution measured from air pollution monitoring stations in Hiroshima Prefecture and the effects of ambient air pollution levels on respiratory symptoms and eye irritations. The current study used health data from the Hiroshima Community Health Study conducted from 1977 until 1992. The health effects of air pollution were studied on adult, non-smoking women exposed to different concentrations of air pollution in Otake, Kure, Takehara, Mihara, Fukuyama City and the Kaita District.

MATERIALS AND METHODS

Health Measures

Health data were extracted from the Hiroshima Community Health Study conducted in 1977–1992^{24,25,33–46)}. A total sample of 13,836 adult, non-smoking women, aged from 40–59 years old who had resided in the study area for more than 3 years was taken in the cities of Otake, Kure, Takehara, Mihara and Fukuyama and in Kaita Town. The data had been taken by stratified random sampling (40–44, 45–49, 50–54 and 55–59 years old) with proportional numbers. During adjustment, those who had been exposed to high levels of air pollution in the work place were excluded. Since, the data per group in each study area was not available, the present study used the total number of population subjects in

Table 1. The numbers of population sample in each study area

Year	Place					
	Otake	Kure	Takehara	Mihara	Fukuyama	Kaita
1977	158	269		335	499	165
1978	174	227	176	167	463	169
1979	174	261	173	174	438	168
1980	154	284	342	160	419	175
1981	163	240	320	133	430	178
1982		251	316	141	423	163
1983		230	283	129	407	141
1984		141	329	118	231	
1985	121	116	295		126	172
1986			272			
1987	100		320			
1988			341			
1989			360			
1990			374			
1991			381			
1992			367			

each study area to be analyzed. The numbers of population sample observed in each study area are shown in Table 1. Women were chosen in this study to minimize the influence of occupational exposure. Most of the study was conducted annually between September and October and only a few studies were carried out between October and November. Information on eye, nose-throat (NT) irritations and cough symptoms was obtained by trained interviewers using a Japanese translation of the standardized questionnaire, British Medical Research Council: Instructions for the Use of the Short Questionnaire on Respiratory Symptoms. The eye irritation data chosen for this study were itchiness and lacrimacy. The respiratory symptom data taken for this study including runny nose, sore throat, cough, phlegm, shortness of breath (SOB) and sums of cough with phlegm and SOB.

Air Pollution Measures

Air pollution data were obtained from the White Paper on the Environment in Hiroshima Prefecture from 1977–1992^{7–22}). The data were taken from the ambient air pollution monitoring systems in each study area. The Ambient Air Pollution Monitoring Systems in Hiroshima Prefecture which were introduced in 1971, indicate the current state of air pollution. The Monitoring Stations measure the conditions of air pollution for 24 hours continuously and send the information to the Monitoring Center in Hiroshima City through radio communications. These monitoring

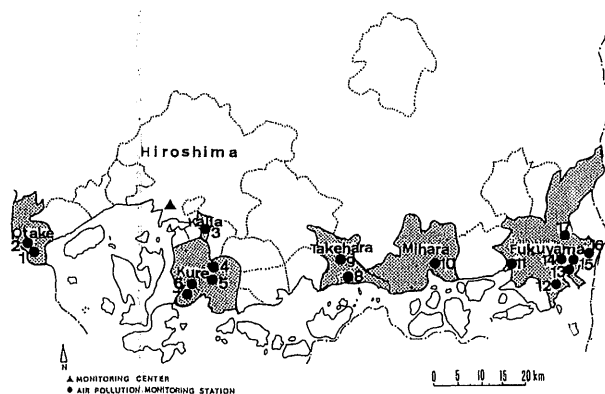


Fig. 1. Ambient Air Pollution Monitoring Stations in each area

stations with their warning systems are used to reduce the negative impact of air pollution from factories and industrial areas. The annual average concentrations of SO₂, NO₂, SPM and O_x concentration were used as the pollution measures. Figure 1 shows the location of the study areas and of the ambient air pollution monitoring stations in each study area. As shown in Table 2, each air pollutant variable used for the study was taken from the same monitoring system during the study period.

Statistical Methods

Statistical analysis was conducted separately for the two measures. Because the number of population samples in each area per year was dif-

Table 2. Ambient air pollution monitoring stations in the study areas

District	Monitoring Station		Parameter to be Measured			
	Name	Place	SO ₂	NO ₂	O _x	SPM
Otake	1 Yumi Park	Yumi, Otake City	○	○	○	○
	2 Yubune Housing Estate	Yubune-cho, Otake City	○	○	○	○
Kaita	3 Kaita High School	Kaita Town, Aki District	○	○		○
Kure	4 Kamiyamada Primary School	Fushihara, Kure City	○	○	○	
	5 Nishi Fire House	Chuo Ward, Kure City	○			○
	6 Miyahara Primary School	Miyahara, Kure City	○	○	○	
	7 Nabeyama Housing Estate	Kegoya, Kure City	○			
Takehara	8 Takehara City Office	Takehara-cho, Takehara City	○	○	○	○
	9 Kamogawa Junior High School	Takehara City	○			
Mihara	10 Mihara 2nd Junior High School	Kojyodori, Mihara City	○	○	○	○
Fukuyama	11 Matsunaga Branch Office	Matsunaga-cho, Fukuyama City			○	
	12 Mukaigaoka Junior High School	Minami Mukaigaoka, Fukuyama City	○	○		
	13 Akebono Primary School	Akebono-cho, Fukuyama City	○	○	○	
	14 Minami Primary School	Meiji-cho, Fukuyama City	○	○	○	○
	15 Teshiro Primary School	Minami Teshiro-cho, Fukuyama City	○	○	○	
	16 Baien Junior High School	Kasuga-cho, Fukuyama City	○	○	○	
	17 Otsuno Primary School	Daimon-cho, Fukuyama City	○	○	○	

ferent, the percentage of respiratory symptoms and eye, NT irritations symptoms as a ratio of population sample was calculated. It was expressed as a percentage of the symptoms. In correcting for air pollution variables, the means of each pollution variable taken from different stations in each area/ year were calculated and used for the main pollution measures.

The association between air pollution and health symptoms was evaluated by individual multiple linear regression analysis. The concentrations of SO₂, NO₂, SPM and O_x of the same year and area with the health measures were used separately as independent variables. Indi-

vidual symptoms such as eye irritations, NT irritations and respiratory symptoms were used as the dependent variable in multiple linear regression analysis. The logistic models were also fitted to these data sets using the maximum likelihood method. The air pollution indices were fitted by symptom prevalence as the dependent variables. Logistic regressions were conducted for each variable.

RESULTS

The trends of air pollution in each study area during the study period are shown in Fig. 2. It is shown that most of the patterns of SO₂ con-

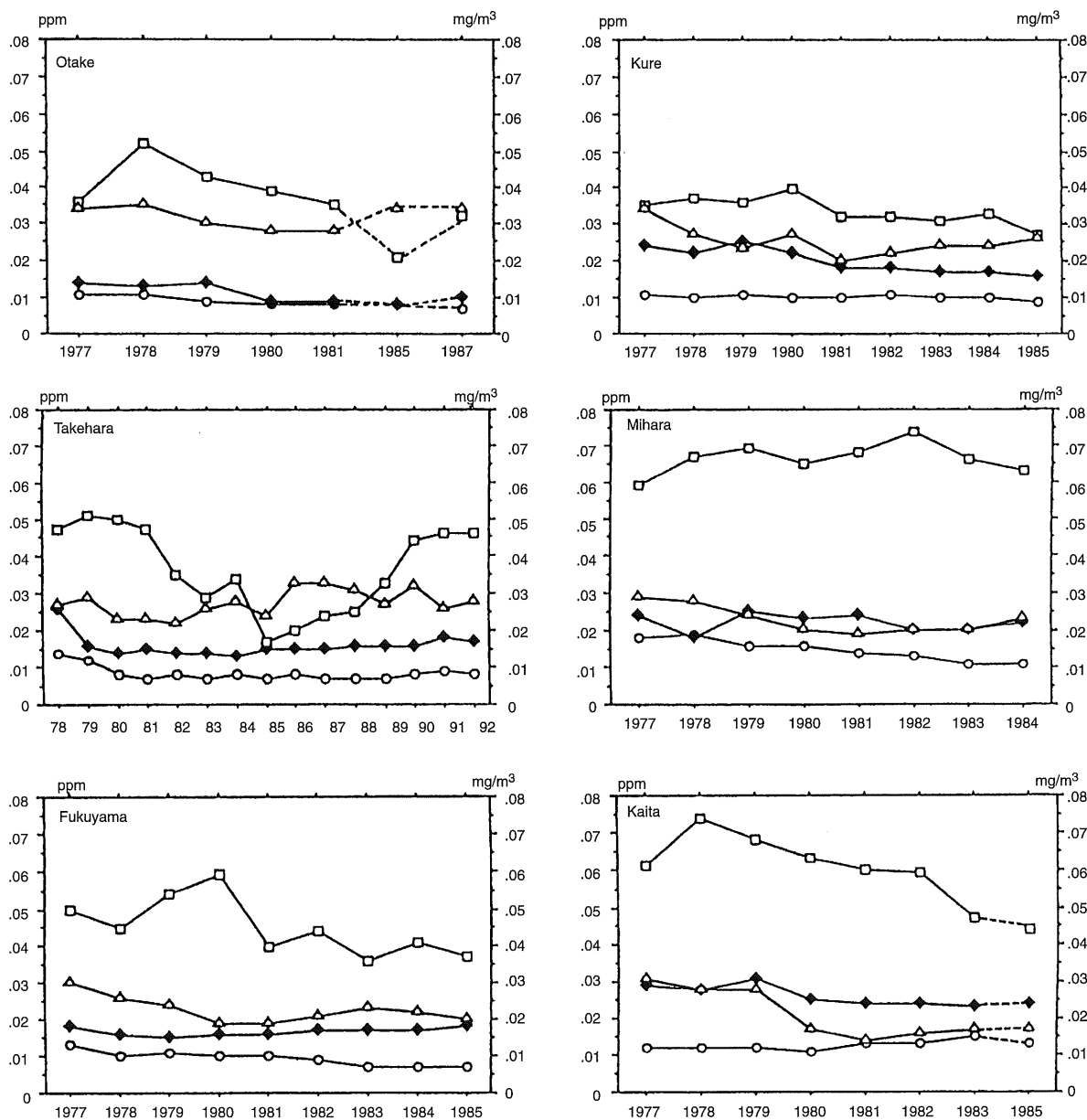


Fig. 2. Annual average concentrations of SO₂ (ppm), NO₂ (ppm), SPM (mg/m³) and O_x (ppm) in each study area

—○— SO₂ —◆— NO₂ —□— O_x —△— SPM
 Note: ---- No health study was conducted.

centration in each study area were decrease, except in Kaita Town. Annual average concentrations of SO₂ were high in the early study period, and from 1979 the air pollution level became lower than in the years before. The patterns of NO₂ in Takehara, Mihara and Fukuyama were increase from 1981. Although the concentrations did not exceed 0.06 ppm as a maximum concentration standard of NO₂ in Japan, the patterns of NO₂ level in Otake, Takehara, Mihara, Fukuyama City and Kaita Town became higher in the mid study period. The increments are almost constant until the end of the study period. The results also revealed various trends in the SPM concentration in the study areas, but most of the trends became higher after 1980. It was also shown that most of the air pollution levels of SO₂, NO₂ and SPM were decreasing in 1980. As shown in Fig. 2, O_x concentrations in Mihara City and Kaita Town were higher, compared with the other cities. Trends of O_x concentrations in Takehara City were on the increase at the end of the study period. Table 3 shows the correlation coefficient between SO₂, NO₂, SPM and O_x in the study areas. The correlations between SO₂ and NO₂, SPM are high. The correlations between NO₂ and SPM are also high. All the correlations were significant (p<0.01). Meanwhile, O_x negatively correlated with SO₂, NO₂ and SPM.

Table 4 shows the results of multiple regression analysis. It shows the partial correlation coefficient between the annual average concentration

of air pollutants and the symptoms reported by subjects. There was a statistically significant association between the annual average concentration of SO₂ and lacrimacy, runny nose and cough (p<0.05).

The robustness of these results was tested by using different estimation methods and other specifications of the model. The statistical significance of the association of the models with the logarithm of the SO₂ as the independent variable and cough as the dependent variable was similar to that for the model with the untransformed SO₂ concentration. The result was also similar for NO₂ as the independent variable and runny nose as the dependent variable. This similarity probably indicates that the prevalence data had a normal distribution because of the relatively high symptom prevalence in this panel.

Figure 3 shows the regression lines between log mean annual concentrations of SO₂ and lacrimacy (lacrimacy= 5.7 log SO₂ + 14.279, R²= 0.017), runny nose (runny nose= 1.537 log SO₂+ 10.442, R²= 0.003) and cough (cough= 19.922 log SO₂ - 0.354, R²=0.087). Moreover, as shown in Table 4,

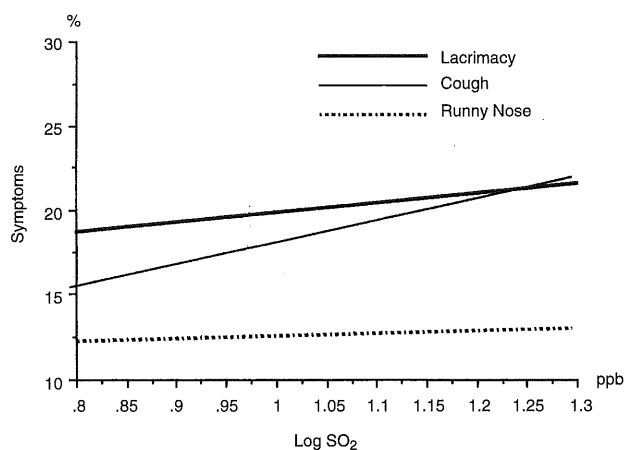


Fig. 3. Regression lines between log mean annual SO₂ concentrations and symptoms. All trends of regression lines are significant (p<0.05).

Table 3. Correlation coefficient between SO₂, NO₂, SPM and O_x in the study areas

	SO ₂	NO ₂	SPM	O _x
SO ₂	1.000	0.623**	0.688**	-0.224
NO ₂		1.000	0.606**	-0.337
SPM			1.000	-0.343
O _x				1.000

Note: **p<0.01

Table 4. Partial correlation coefficients between air pollution factors and symptoms
Data used are from 1977–1992 in Hiroshima Prefecture

Air Pollution Factor	Eye Irritations		Respiratory Symptoms					Sum of Cough with Phlegm & SOB
	Lacrimacy	Itch	Runny Nose	Sore throat	Cough	Phlegm	SOB	
SO ₂	0.096*	-0.047	0.229*	-0.040	0.130*	0.036	0.101	-0.113*
NO ₂	-0.006	0.100	-0.321*	-0.114	-0.095	0.103	-0.022	-0.103
SPM	-0.046	-0.124	-0.172	0.174	-0.163	-0.017	-0.051	0.161
O _x	0.073	0.025	-0.303	0.106	-0.098	0.369**	-0.044	0.074

Note: *p<0.05
**p<0.01

Table 5. Association between symptoms and exposure to ambient air pollution in a population of 13, 836 adult, non-smoking women in Hiroshima Prefecture, 1977–1992.

Air Pollution Factor	Eye Irritations		Respiratory Symptoms					Sum of Cough with Phlegm & SOB
	Lacrimacy	Itch	Runny Nose	Sore throat	Cough	Phlegm	SOB	
SO ₂	-0.039¶* (0.046)§	-0.031 (0.046)	-0.017* (0.073)	-0.041 (0.041)	-0.101* (0.046)	-0.030 (0.048)	-0.087 (0.057)	-0.064* (0.031)
NO _x	0.047 (0.046)	0.036 (0.046)	-0.018* (0.076)	0.059 (0.042)	-0.046 (0.044)	-0.088 (0.049)	-0.056 (0.058)	-0.035 (0.030)
SPM	0.001 (0.045)	0.017 (0.045)	0.090 (0.074)	-0.070 (0.041)	-0.038 (0.044)	-0.023 (0.048)	-0.031 (0.057)	0.024 (0.030)
O _x	-0.065 (0.046)	-0.072 (0.046)	0.010 (0.073)	-0.073 (0.041)	-0.040 (0.044)	0.045** (0.048)	-0.066 (0.058)	-0.022 (0.030)

Note: ¶ Logistic regression coefficient

§ Standard error of the regression coefficient

*p < 0.05

**p < 0.01

there was a significant association between mean O_x levels and phlegm (p<0.01). The results of the study revealed that there was no significant correlation between the mean SPM level and the symptoms reported by subjects. In contrast, mean NO₂ levels and runny nose symptoms in the study subjects were significantly correlated negatively. The result was also similar for the SO₂ concentration and the sum of the symptoms. It was found that SO₂ was significantly correlated negatively with the sum of the symptoms.

Table 5 shows the associations between symptoms and exposure to ambient air pollution in the population subjects. The associations were assessed using the logistic regression model described previously and presented as the logistic regression coefficient and standard error of the mean.

DISCUSSION

The present study was limited to investigate the trends of air pollution and its effects on human health. The study subjects were adult, non-smoking women drawn randomly from the six study areas. Adult, non-smoking women were chosen for this study to minimize potential confounding factors such as smoking and occupational hazards. Moreover, the study subjects had resided in those areas for more than three years. The study subjects were interviewed by using a Japanese translation of a standardized questionnaire. The study areas have several ambient air pollution monitoring stations that monitor the current state of air pollution continuously. However, in Mihara City, the number and location of ambient air monitoring stations was not representative for that area. Most of the study was carried out in the lowest pollution season (September-October). This was to minimize confound-

ing factors such as the use of combustion space heating appliances in the home and winter air pollution.

As can be seen from the trends of air pollution in the study areas, most of the SO₂ levels were showing a decrement in the study period. Meanwhile, the concentrations of NO₂ and the other pollutants differed by area. Although the study represented only six areas in Hiroshima Prefecture and of Japan as a whole. There are three major air pollution sources in Hiroshima Prefecture: industrial emissions and automobiles; residential heating and cooking; and natural sources. The trends of air pollution caused by mobile sources, such as passenger cars, buses, and trucks have increased since the economic boom in this country⁵. In contrast, the emission of sulfur dioxide from factories in highly polluted industrial areas is being monitored by air pollution monitoring with warning systems. As a result, SO₂ levels were on the decrease in the study areas. Meanwhile, the trends of NO₂, SPM, O_x levels in most of the study areas were on the increase.

In the present study, moderate annual average fluctuations in SO₂ levels induced a statistically significant increase in cough, lacrimacy and runny nose symptoms in the study subjects. Increases in the cough symptoms (p<0.05), lacrimacy (p<0.05) and runny nose (p<0.05) when SO₂ levels were high, suggest that the observation was not due to chance. The Gardanne Coal Basin Study revealed that moderate daily changes in SO₂ levels induce a significant increase in the prevalence of pulmonary symptoms and have correlations with eye irritation and the prevalence of runny nose⁴. In North America, recent data indicate that sulfates are associated with indices of

respiratory morbidity²⁹⁾. Love, G.J. et al also found that the respiratory disease rate is higher in communities exposed to high levels of SO₂²⁷⁾.

In contrast, this study could not prove that a high concentration of NO₂ increases respiratory symptoms in study subjects. The study only found that with low NO₂ levels, there was an increase in runny nose symptoms. However, this was possibly only an allergic seasonal runny nose caused by an allergy to pollen. Further investigation of geographical pollen distribution is necessary to confirm this phenomenon. A question remains whether nose irritation is more closely associated with relatively low annual means of NO₂ concentrations.

This study found that SPM levels have a positive correlation, but were not significant with sore throat and sums of respiratory symptoms in the study subjects. The results of this study also revealed that exposure to high O_x levels has a significant association with phlegm (p<0.01). Photochemical Oxidants are oxidizing secondary pollution substances such as ozone that are produced when nitrogen oxides and hydrocarbons are irradiated by solar light. In this study, high concentrations of SO₂, NO₂, SPM had an association with low levels of O_x in that area. When hydrocarbons are not involved, the high concentrations of NO₂ will absorb the light energy and causes it to split to form nitric oxide and free oxygen atoms. These free oxygen atoms spontaneously react with oxygen gas and nitrogen gas, so there is no accumulation of ozone. High levels of SO₂ and NO₂ will also react with water vapour to form sulfuric acid and nitric acid, respectively. The fine particles also absorb numerous other pollutants on their surface. Therefore, when no hydrocarbons are involved and the concentrations of NO₂, SO₂ and SPM are high, no accumulation of ozone will occur in that area. The increasing levels of O_x in recent years may be a result of the increasing number of air pollutants caused by motor vehicles.

In summary, air pollution patterns differ by place. SO₂ levels are decreasing currently, meanwhile the levels of NO₂, SPM and O_x are increasing. High levels of air pollutants such as SO₂, O_x are associated with an increase in eye irritation, nose irritation and respiratory symptoms in the community living in that area. The increasing number of motor vehicles in recent years with their relationship with an increasing level of photochemical oxidants may cause an increase in respiratory symptoms in the community. However, it seems that SO₂ is the only ambient air pollutant with well documented unfavorable respiratory effects at ambient concentrations. Again, all these issues require further investigation. Studies are also required to confirm the existence of these sorts of effects in other countries.

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