行政院國家科學委員會補助專題研究計畫成果報告

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※臭氧及 $PM_1/PM_{2.5}/PM_{10}$ 氣懸微粒之加成健康效應及風險評估 ※
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執行期間： 89 年 8 月 1 日至 91 年 7 月 31 日

計畫主持人：陳保中
共同主持人：鄭尊仁

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□赴國外出差或研習心得報告一份
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□出席國際學術會議心得報告及發表之論文各一份
□國際合作研究計畫國外研究報告書一份

執行單位：台灣大學公共衛生學院職業醫學與工業衛生研究所

中　華　民　國　90　年　10　月　31　日

行政院國家科學委員會專題研究計畫成果報告

臭氧及 $PM_1/PM_{2.5}/PM_{10}$ 氣懸微粒之加成健康效應及風險評估

Ozone and $PM_1/PM_{2.5}/PM_{10}$ particulate joint health effect and its risk assessment

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主持人：陳保中

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執行機構及單位名稱：台灣大學公共衛生學院職業醫學與工業衛生研究所

一、中文摘要

本研究使用時間系列追蹤研究設計，以探討臭氧、氣懸微粒 $PM_{10}/PM_{2.5}$**，及二氧化氮對國小學童肺功能之影響。本研究於** 2000 **年秋季九天及** 2001 **年春季十三天進行，共有** 52 **名古亭國小學童參予，研究期間每天於早上學童到校後以及放學回家前各作五次尖峰吐氣流量率**(PEFR)**之測量，並記錄每天活動及呼吸道症狀。並以古亭國小裡環保署空氣品質自動監測站數據作為暴露評估之依據。研究期間的臭氧平均白天八小時濃度為** 28.33 ppb(**最大值為** 75.31 ppb)**，**PM_{10} **與** $PM_{2.5}$ **平均白天八小時濃度分別為** 55.73 ì g/m^3 **與** 33.86 ì g/m^3**。我們發現前一天的臭氧平均及尖峰濃度會對學童當天早上與下午的尖峰吐氣流量率造成下降的影響，當天臭氧的平均及尖峰濃度會對學童當天下午的尖峰吐氣流量率造成下降的影響。但我們並未發現氣懸微粒** $PM_{10}/PM_{2.5}$ **及二氧化氮與學童尖峰吐氣流量率之間的相關性。**

關鍵詞：臭氧、氣懸微粒、尖端呼氣流速、呼吸道症狀、風險評估、國小學童、時間系列追蹤研究。

Abstract

We assessed the contributions of particulate matter (PM_{10}, $PM_{2.5}$), NO_2, and ozone concentrations to peak expiratory flow rate (PEFR) in 52 schoolchildren for 22 days during two periods in 2000 and 2001. We measured peak flow in the morning on children's arrival at school and in the evening before departing from school. Air pollutant concentrations were obtained from the Taiwan EPA fixed-site air monitoring station. Mean daytime (8am-4pm) ozone concentration was 28.33 ppb (maximum=75.31 ppb), and mean daytime particulate level was 55.73 ì g/m^3 (maximum 162.45 ì g/m^3) for PM_{10} and 33.86ì g/m^3 (maximum 68.93 ì g/m^3) for $PM_{2.5}$.

We found a significant negative association between morning PEFR and pre-day mean daytime ozone concentrations(β-coefficient = -0.16; p=0.01), and evening PEFR and same-day (β-coefficient = -0.20; p=0.02)and pre-day mean daytime ozone concentrations (β-coefficient = -0.17; p=0.04), after adjusted gender, height, symptom, season, temperature, and co-pollutants. But we were not able to demonstrate any association between daily PEFR and mean daytime PM_{10}, $PM_{2.5}$, and NO_2.

Keywords: ozone, particulates, peak expiratory flow rate, respiratory symptoms, risk assessment, school children, time-series panel study.

二、緣由與目的

In the last few years, several studies have reported significant associations between air pollution and daily mortality and various markers for acute respiratory morbidity, including hospital admissions, hospital emergency and outpatient clinic visits, exacerbation of respiratory symptoms, lung functions changes, and school absenteeism in Europe and America [1,2]. However, there are still many issues to be clarified before we know the real causal relationship between air pollution and health effects.
Respiratory symptoms and lung function as indices of respiratory health effects have been documented in previous studies. Most major pollutants can alter respiratory symptoms and lung function in addition to other health effects when the exposure concentrations are high. In a relatively low dose exposure due to common air pollution, however, each pollutant is not thought to have significant effects on respiratory symptoms and lung function [3]. A joint effect of mixtures of air pollutants is more complicated and still unclear.

Epidemiological field studies have been used to investigate the acute pulmonary effects of ambient ozone and particulates under natural conditions such as children' studies conducted in summer camps, during exercise, and during daily life activities. Such studies can examine the ozone and particulate effect under real time measurements and patterns of ozone and particulates, other air pollutants, and various environmental conditions.

Ozone (O_3), a strong oxidant, is most frequently reported to produce respiratory symptoms and lung function impairment at low level because it may induce lipid peroxidation and production of cycloxygenase that trigger the neural receptors of the airway [4,5]. Studies of lung function provide the most consistent evidence of ozone-induced effects. Five epidemiological studies of daily life [6-10] involved full spirometric measurements for the children. The Harvard six cities study [6] and our study [10] showed that lung function damages occurred even when the peak ozone level was < 80 ppb, and no clear threshold level has yet been established. Larger negative coefficients were determined for the children with a history of chronic phlegm in a study in Mexico [7], but our study [10] and a Dutch study [8] did not reach the same conclusions. It is not clear whether subjects with respiratory symptoms or asthmas are more sensitive to the effects of ozone on lung function.

Particulates 10 mm in aerodynamic diameter (PM_{10}) also have a negative effect on respiratory symptoms and lung function in many studies, but the mechanism is still unclear [11,12]. Fine particulates 1 or 2.5 mm in aerodynamic diameter (PM_1/$PM_{2.5}$) have not been understood their roles on the impairment of lower respiratory airways.

Very small, often statistically insignificant associations between particulate pollution and upper respiratory symptoms (URS) were observed. The association with lower respiratory symptoms was larger and usually statistically significant. The estimated % increase in reported lower respiratory symptoms (LRS) associated with a 10 ì g/m3 increase in PM_{10} was as high as 5.1% for general children and 2.4% for asthmatic children. Cough was typically associated with particulate pollution with a 10 ì g/m3 increase in PM_{10} as high as 28 % for general children and 5.2% for symptomatic or asthmatic children.

Several studies have used $FEV_{1.0}$ and PEFR measurements as an indicator of acute changes in lung function. The estimated % decrease in $FEV_{1.0}$ associated with a 10 ì g/m^3 increase in PM_{10} was as high as 0.35% for general children. A 10 ì g/m^3 increase in PM_{10} was associated with a 0.16% to 0.19% decrease for general children and a 0.04% to 0.43% for symptomatic or asthmatic children in PEFR measurements. As with FEV1.0, the strongest associations with PEFR included particulate pollution over the previous several days, allowing for a lag in effect.

Harvard six cities study [6] found O_3 to have a contemporaneous effect on lung function or a short lag structure in comparison with the lag structure often found for particulate pollution. Gold and colleagues [13] also found both O_3 and particulates in the reduction of PEFR with shorter lags between exposure and reduction in PEFR for O_3 than for particulate exposure (0-4 vs. 4-7 days). The joint effect of 7 days of exposure to the interquartile range of $PM_{2.5}$ (17 microg/m^3) and O_3 (25 ppb) predicted a 7.1% (95% CI, 11.0-3.9) reduction in morning PEFR.

Although the problems of air pollution in Taiwan are relatively severe, it was not until recently that the health effects associated with air pollution were reported [10, 14 - 18]. From the preliminary analyses of the pollution monitoring data, we know that the major pollutants in Taiwan are O_3 and particulates in most places and sulfur dioxide (SO_2) pollution in others [19].

Children are usually selected as the study population of air pollution epidemiology. Firstly, children usually do not smoke and the result will be less likely to be confounded, especially the relation between exposure and changes in respiratory symptoms and lung function. Secondly, children's respiratory organ system is under developing and may be more vulnerable to air pollution. As they are our future hope, they deserve special attention. Thirdly, children frequently have their outdoor activities in the daytime, while air pollution levels are usually quite high during the same period of the day, and they are more likely to be exposed.

三、材料與方法

Study population

A cross-sectional survey of respiratory questionnaire mainly adapted and modified from the WHO childhood respiratory questionnaire was conducted for all grade 4-5 children of Gu-Ting primary schools. The parental response questionnaire was divided into the following 6 parts: demographic data, respiratory symptoms and diseases, nutritional status, housing conditions, children's bedrooms, and possible sources of indoor air pollution such as household smoking, pets, fowls, coal stove used, tea gas-cooker used, incense burning, mosquito repellent burning, indoor planting, and home dampness. Self-reported respiratory diseases such as sinusitis, wheezing or asthma, allergic rhinitis, bronchitis, and pneumonia were included in a history of respiratory disease diagnosed by medical doctors.

We randomly selected two classes for each grade and with willingness, 52 of 4th and 5th grade students (Table 1) participated in this study. We measured peak flow on school days during two periods between October 23 and November 3 and between March 12 and 28, 2001.

Table 1 Summarized information of the subjects

Information	Students in the study (Total number = 52) Number (%)
Boys	28 (53.8)
Questionnaire completed by parents	50 (96.2)
History of respiratory diseases	
Sinusitis	4 (7.7)
Wheezing or asthma	8 (15.4)
Bronchitis	16 (30.8)
Pneumonia	1 (1.9)
Allergic rhinitis	18 (34.6)
Symptoms[a] of current and pre-day	23.4

[a] Daily symptoms during the study periods including

cough, rhinorrhea, sneeze, phlegm, headache, fever, nausea, stomachache, bellyache, diarrhea, and vomit.

Under supervision from research technicians, subjects performed the PEF test on arrival at school and before departing from school. Each subject performed five peak flow maneuvers on his or her own Trudell Medical TruZoneTM Peak Flow Meter. The reading and reported symptoms of current day's cough, phlegm, and sneeze etc. were recorded by the observing technician.

Air pollutant data

O_3 and $PM_1/PM_{2.5}/PM_{10}$ particulate measurements will be available for at least 2 weeks before the follow-up periods. The hourly concentrations of O_3 and PM_{10} will be obtained from the fixed-site air monitoring station, which is responsible by the Environmental Protection Administration (EPA), on the campus of the primary school. The other air pollutants including sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2) also are available in the station. The instrumentations used in the stations are UV absorption for O_3, b-gauge for PM_{10}, ultraviolet (UV) fluorescence for SO_2, non-disperse infrared absorption for CO, and chemiluminescence for NO_2. The air quality is measured by comparing the air pollution levels with the appropriate National Ambient Air Quality Standards (NAAQS) of Taiwan [20] for each air pollutant. Meteorologic data, such as atmospheric temperature and rainfall, are also obtained from the same monitoring station.

Statistical method

Each subject performed five-peak flow maneuvers and the highest reading was took into calculation. We use single and multi-pollutants linear mixed effect models to determine associations between PEFR and explanatory variables. Exposure variables were also lagged up to 5 days. All models included gender, height, mean daytime temperature, daily symptoms, and season. All analyses were performed using SAS and S-plus statistical software.

四、結果

Air quality

During the study period (including 5 days before the two periods), the mean daytime (8am-4pm) ozone concentration was 28.33 ppb (maximum = 75.31 ppb), and 6 days exceeded 60 ppb (Air quality standard of Taiwan). Daily maximum ozone concentration exceeded 120 ppb once (122.3 ppb). The mean daytime particulate level was 55.73 ì g/m^3

Table 2 Correlation coefficients for daily mean daytime values for ozone, PM_{10}, $PM_{2.5}$, NO_2, and temperature

		Ozone ppb	PM_{10} ì g/m^3	$PM_{2.5}$ ì g/m^3	NO_2 ppb	Temp. ℃
Ozone	ppb	1.00				
PM_{10}	ì g/m^3	0.37*	1.00			
$PM_{2.5}$	ì g/m^3	0.48**	0.89**	1.00		
NO_2	ppb	0.12	0.57**	0.68**	1.00	
Temp.	℃	0.36*	0.07	0.38	-0.13	1.00

*, p<0.05; and **, p<0.01.

FIGURE 1 Daily air pollution and temperature readings during the 2 periods of the study

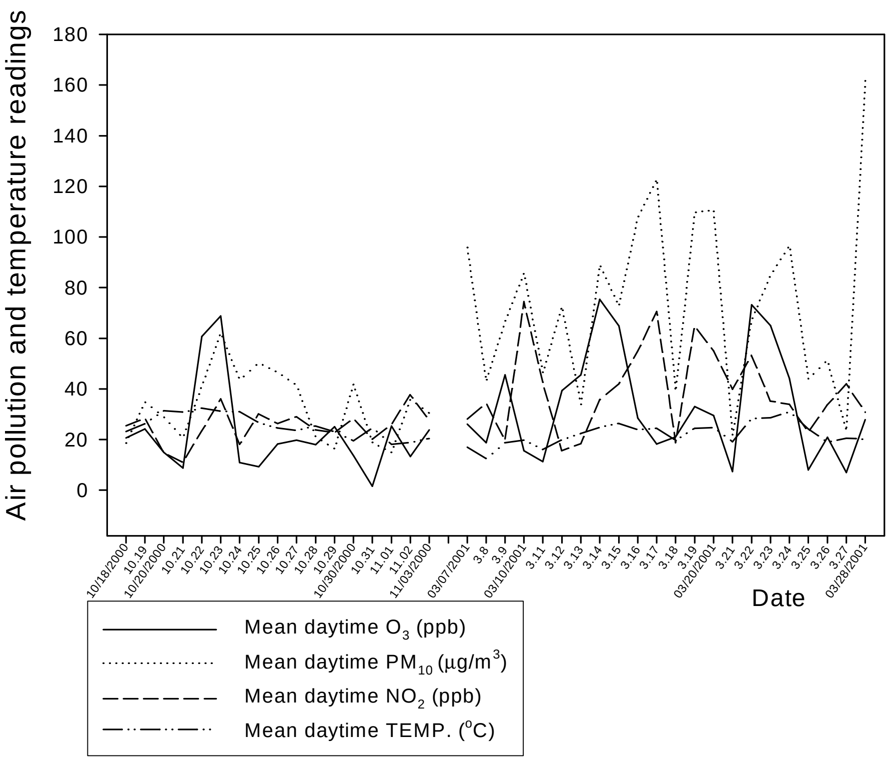

Table 3 Single-pollutant linear mixed effects models of evening PEFR (liters per minute)[a]

Mean daytime (8am-4pm)	â (SE)	p-value
Ozone (ppb)	-0.18 (0.08)	0.03
PM_{10} (ì g/m^3)	0.05 (0.06)	0.38
$PM_{2.5}$(ì g/m^3)	0.01 (0.15)	0.96
NO_2 (ppb)	0.21 (0.10)	0.04

[a] Adjusted for gender, height, mean daytime temperature, daily symptom, season, and SO_2.

Table 4 Multi-pollutant linear mixed effects models of evening PEFR (liters per minute) [a]

	â (SE)	p-value
Ozone (ppb)	-0.20(0.08)	0.02
PM_{10} (ì g/m^3)	0.04(0.08)	0.62
NO_2 (ppb)	0.19(0.12)	0.13

[a] Adjusted for gender, height, mean daytime temperature, daily symptom, seasons, and SO_2.

(maximum 162.45ì g/m^3 which exceeded the standard 125ì g/m^3) for PM_{10} and 33.86ì g/m^3 (maximum 68.93ì g/m^3)for $PM_{2.5}$. The mean daytime NO_2 concentration was 33.31 ppb. The mean daytime temperature was 23.63℃. All pollutant levels were higher in the spring month (March). PM_{10} and $PM_{2.5}$ were highly correlated [R = 0.89 (Pearson correlation coefficient)] (Table 2). Daily mean for the pollutants are demonstrated in Figure 1.

Single and multi-pollutant model

We controlled for co-pollutants, gender, height, mean daytime temperature, daily symptom, and season in all mixed effects models. In single-pollutant model, reduced evening peak flows were associated with daytime mean ozone exposure (Table 3). Although the mean daytime PM_{10} did not significantly contribute to the single-pollutant model, it was retained the multi-pollutant model as the aim of the modeling was to determine the effect of ozone on lung function after adjusting for co-pollutants.

Multi-pollutant model still suggested a linear declining relation between ozone and lower evening peak flow (Table 4). However, the effect of NO_2 on increasing PEFR in single-pollutant model became non-significant after controlling other co-pollutants.

Lagged effects of ozone on PEFR

Association between lagged value of daytime mean and maximum ozone and PEFR are presented in Table 5. The model suggested that mean daytime Ozone contributed to the reduction of both morning and evening PEFR. The associations were statistically significant for the same day and up to lag 1 day. Results were similar for maximum daytime ozone.

五、討論

This study found a significant negative association between daily PEFR and same-day and pre-day mean daytime ozone concentrations. We were not able to demonstrate any association between daily PEFR and mean daytime PM_{10}, $PM_{2.5}$, and NO_2 in either single pollutant or multi-pollutant models.

Table 5 Association between lagged values of mean and maximum daytime ozone and PEFR [a]

	Morning PEFR		Afternoon PEFR	
Ozone	â (SE)	p-value	â (SE)	p-value
Mean daytime				
Same day			-0.20 (0.08)	0.02
Lag 1	-0.16 (0.06)	0.01	-0.17 (0.08)	0.04
Lag 2	-0.01 (0.06)	0.83	-0.09 (0.08)	0.25
Maximum daytime				
Same day			-0.13 (0.06)	0.03
Lag 1	-0.12 (0.04)	0.01	-0.14 (0.06)	0.02
Lag 2	-0.02 (0.04)	0.62	-0.07 (0.05)	0.15

[a] Adjusted for gender, height, symptom, season, temperature, SO_2, NO_2, and PM_{10}.

The study location is located in the center of Taipei city, and the main sources of air pollution are from traffic. In the study periods, the mean daytime ozone exceeded 60 ppb (Air quality standard of Taiwan) 6 times, but none of them exceeded 80 ppb (US EPA). Furthermore, the ozone levels of this fixed-site air monitoring station are low comparing other sites in Taipei and Taiwan. Despite the concentration of daytime ambient ozone were not high, we found significant negative associations between PEFR and mean daytime ozone concentration.

In our study there were greater effects for mean daytime ozone concentration than for maximum daytime ozone concentration. Similar patterns of results have been reported by others [7].

Our findings of the associations between lung function and daily mean ozone concentrations are similar to those from other reported studies [8,13]. A 1-ppb increment in same-day mean daytime ozone resulted in about 0.2 liters/min decrease in evening PEFR. A 1-ppb increment in pre-day mean daytime ozone resulted in a 0.2 liters/min decrease in morning PEFR.

In conclusion, we suggest that current levels of ambient ozone in Taipei may have an adverse health effect on lung function of schoolchildren.

六、計畫成果自評

The preliminary analysis demonstrated that there was a causal effect of ozone on schoolchildren lung function. However, we did not find any significant effect of particulate, even fine particulate. This result will be published in an international journal.

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