Effects of Asian dust storm events on daily mortality in Taipei, Taiwan

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Introduction

- It is generally accepted that severe air pollution episodes, which are characterized by high levels of particulate pollution and/or sulfur dioxide, have been associated with substantial excess mortality.

Examples include

- Episode in Donora, Pennsylvania in 1948; and Episode in London in 1952 *(Logan, 1953)*.
- Several studies of less severe episodes also suggested mortality effects associated with moderately elevated pollution levels.

- Many epidemiologic studies have provided evidence of an association between airborne particles and daily mortality. Most of these studies have been conducted in urban areas where fine particles (less than 2.5 μm) are the major type of air pollution.
- Fine particles: derived chiefly from combustion of fossil fuels in processes such as transportation, manufacturing, and power generation.

- Fine particles are of the greatest health concern because they can be inhaled most deeply into the lungs.
- Coarse particles (between 2.5 and 10μm): originate primarily from geologic sources (soil and other crystal materials).
- Episodes of high levels of coarse particles are usually associated with high wind speeds that may tend to diminish the concentrations of fine particles and other combustion-related pollutants.

- Schwartz *et al.* (1999) found no evidence that mortality was elevated on dust storm days in Spokane, Washington.
- Ostro *et al.* (1999) found an association between PM_{10} and daily mortality in the Coachella Valley, a desert resort and retirement area east of Los Angles, where coarse particles of geological origin typically comprise approximately 50-60% of PM_{10} and can exceed 90% during wind events.

- Kwon *et al.* (2002) reported that Asian dust events were weakly associated with risk of death from cardiovascular and respiratory causes. However the observed association was not statistically significant.
- The objective of this study was to assess the possible effects of Asian dust storms on the mortality of residents in Taipei, Taiwan, during the period from 1995-2000.

Materials and Methods

- Taipei, the capital city of Taiwan, is situated in a basin in the north of Taiwan, and has a population of approximately 2.6 million. Vehicular traffic is thought to be the only source of ambient air pollution.
- Asian dust-storm events encountered in Taiwan are associated with northeastern winds of the winter monsoon, air quality monitoring stations along the north and northeast coasts of Taiwan would show the largest impacts of the dust-storm events *(EPA/Taiwan, 2001)*.

- This indeed turns out to be the case, with particular enhancements/spikes occurring in PM_{10} measurements from Yangmingshan station (826 m altitude). They can be used to unambiguously identify the major Asian dust-storm events in Taipei.
- We identified 39 dust storm episodes (index days) between 1995 and 2000 in Taipei city (Table 1).

Table 1. Dust storm days in Taipei, *1995-2000*

Year	Date
1995	28 February, 4 March, 12, March, 22-23 March, 25 April, 15 May.
1996	6 March, 8-10 May, 12 May.
1997	2 January, 28 April.
1998	18-19 April.
1999	7 January, 27 January, 3 February, 12 February, 19 February, 6-9 April.
2000	3 January, 5 January, 24-25 March, 28-31 March, 12 April, 22 Apil, 27-28 April, 1 May, 14 May.

- **Mortality Data**
  - We obtained counts of total daily deaths within Taipei City from the Department of Health.
  - Deaths due to accidents (ICD-9 codes 800-999) and deaths occurring outside of the city were excluded from the analysis.

- The deaths were divided into the following two groups according to the ICD-9:
  1) disease of the respiratory diseases (ICD-9 codes 460-519); and
  2) diseases of circulatory systems (ICD-9 codes 390-459).

- Daily measurements of air pollution from the 6 air quality monitoring stations operated by the Taiwan Environmental Protection Administration (EPA) wee used.
- Daily information on mean temperature and mean humidity was provided by the Taipei Observatory of the Central Weather Bureau.

- **Statistics**

1. Deaths on the index days were compared with deaths on the comparison days.
2. Comparison days were the same week days as the corresponding index days and when dust storms did not occur on that day. We selected two comparison days for each index day, 7 days before the index day and 7 days after the index days.

3. If dust storms occurred on a comparison day, the day 14 days preceding/following the index day were selected.
4. We examined the effects of dust storms on the same day and 1, 2, and 3 days after the storm events.

5. The results are presented as a percentage increases associated with dust events. The percentage was calculated as the difference of the average number of deaths which occurred on index and comparison days and divided by the average number of deaths on comparison days.

Results

- The average PM_{10} level for the index days was 125.94 $\mu g/m^3$, which was 68.14 $\mu g/m^3$ higher than the average for the comparison days.
- The levels of the other pollutants (CO, NO_2, SO_2) were very similar. However, the mean O_3 level was higher for index days than for comparison days. Temperature and relative humidity were lower during the dust storm days.

Table 2. Mean levels of environmental variables and daily death counts on dust storm days (index days) and comparison days in Taipei, 1995-2000

Variable [a]	Index days (n=39)	Comparison days (n=78)	p-value
PM_{10} ($\mu g/m^3$)	125.94 ± 33.61	57.80 ± 32.84	< 0.0001
SO_2 (ppb)	5.62 ± 3.67	5.07 ± 3.77	0.4542
NO_2 (ppb)	35.88 ± 10.74	34.97 ± 10.59	0.6631
CO (ppm*10)	11.72 ± 5.23	11.33 ± 5.18	0.7035
O_3 (ppb)	27.69 ± 9.40	20.91 ± 8.56	0.0002
Temperature(°C)	19.98 ± 4.03	20.45 ± 3.75	0.5375
Humidity (%)	68.64 ± 11.36	78.40 ± 9.28	< 0.0001

[a] values are 24-hour averages

- The mean daily non-accidental death count was slightly higher for the index days than for the comparison days.

Table 3. Estimated percentage increases in the risk of deaths for dust storm days by various lags

	Index days (39)	Comparison days (78)	Percentage increase
The same day			
Total deaths	27.10 ± 3.97	26.97 ± 5.68	0.48%
Respiratory deaths	2.18 ± 1.52	2.60 ± 1.69	-19.27%
Circulatory disease deaths	7.31 ± 2.55	7.32 ± 2.29	-0.14%
1-day lag			
Total deaths	27.03 ± 5.60	26.92 ± 5.26	0.41%
Respiratory deaths	2.74 ± 1.53	2.53 ± 1.57	7.66%
Circulatory disease deaths	7.08 ± 2.16	7.09 ± 2.39	-0.14%

- The effects of dust storms on total deaths and deaths due to circulatory disease were prominent two days after the event. For respiratory deaths, the association was highest on one day after the event and decreased thereafter.

- The strongest estimated effects of dust storms were: an increase of 7.66% in risk for respiratory disease one day after the event, an increase of 4.92% for total deaths two days following the dust storms and 2.59% for circulatory diseases two days following the dust storms, respectively.

Table 3. Estimated percentage increases in the risk of deaths for dust storm days by various lags (con't)

	Index days (39)	Comparison days (78)	Percentage increase
2-day lag			
Total deaths	27.64 ± 6.11	26.28 ± 5.92	4.92%
Respiratory deaths	2.54 ± 1.80	2.58 ± 1.74	-1.57%
Circulatory disease deaths	6.95 ± 2.70	6.77 ± 2.73	2.59%
3-day lag			
Total deaths	25.41 ± 4.82	27.44 ± 5.42	-7.99%
Respiratory deaths	2.31 ± 2.04	2.65 ± 1.89	-14.72%
Circulatory disease deaths	6.64 ± 2.44	7.21 ± 2.60	-8.58%

Discussion

1. As expected, we observed that the Asian dust storms led to enhanced PM_{10} levels in Taipei city.
2. Other combustion-related pollutants (SO_2, NO_2, CO) did not differ from those on the comparison days. This allows us to attribute any adverse effect of the events to PM_{10}, although the mean levels of O_3 is also higher on the index days than the comparison days.

3. Our method can control for confounding by long-term time trends, seasonal patterns and, by definition, control for day of the week-- controls for many confounders by design rather than through statistical modeling.

4. Although the risk estimates were not statistical significant the relative specificity of this finding increases the likelihood that the association between the dust events and daily mortality represents a causal relationship.

5. We observed a 4.92% increase in the risk of death from all causes, which amounts to a 0.72% increase for each 10 μg/m^3 increase in PM_{10}. Our risk estimate is larger than that found in a study conducted by Kwon *et al.* (2002) (a 0.6% increase for each increase of 10 μg/m^3 in PM_{10}, in Seoul, Korea.

6. The risk estimate for respiratory mortality, 1.12% per 10 μg/m^3 increase in PM_{10} is similar in magnitude to results reported elsewhere.
7. For cardiovascular mortality, summary estimates of 1.4% per 10 μg/m^3 increase in PM_{10} have been reported. Our risk estimate is 0.38%, which is far lower than that reported by previous studies.

8. This could result from the fact that our endpoint is all diseases of the cardiovascular system (ICD 390-459), while previous studies have used a more refined endpoint, ischaemic heart disease (ICD 410-414) and the fact that PM-related cardiovascular toxicity is more specific to ischaemic heart diseases.

9. The levels of O_3 is also higher on the index days than on the comparison days. It is difficult to determine which pollutants (PM_{10} or O_3) is responsible for the association. Compared with the particulates, the relationship between O_3 and daily mortality is less consistent. It may be therefore be conceivable that the study finding is due mainly to PM_{10}.

Summary

- Asia dust storm events could increase the risk of daily mortality in Taipei, although none of the associations were statistically significant. This study found greater specificity for associations with respiratory and circulatory deaths, and this increases the plausibility of a causal explanation.