Panel on Environmental Affairs Subcommittee on Improving Air Quality Meeting, 28 January 2011

HKU Study on Impact of Loss of Visibility on Mortality risks: A Report of Regional and Global Importance

Anthony J Hedley on behalf of Environmental Research Group, School of Public Health, University of Hong Kong

1	Title	Thankyou chairman. Good morning honorable legislators. Thank you for asking us, on behalf of our colleagues in the School of Public Health to address the issue of Hong Kong's serious threat to community health from air pollution.
2		We will take a focussed public health approach to this and present our new analyses on the association between daily visibility and daily deaths. We did this analysis to facilitate public understanding of environmental health risks and to correct some previous misleading public statements about the causes of our lost visibility.
3	Slide of harbour	What you see is what you breathe; this obscured view across the harbour is now part of our lifestyle and potential threat to health. Visibility from Central this week has been as low as 4.8 kilometres or less.
4	Slide of hazy days	The HKO records of hazy days are the most obvious manifest evidence of the degradation of our environment. We have sat and watched this curve emerge over 30 years and accelerate over the last 10 years. Exposure to the toxic chemistry of our air is 100% and we have asked the question: is this curve a signal of a long term epidemic of ill-health?
5	Slide of statistical model	We have very good quality data in Hong Kong which allows us to quantify the relationship between daily visibility from the Observatory and registered causes of daily deaths from the Census and Statistics Department. In our analysis, in addition to daily visibility, we have included many other factors which may affect both daily mortality and visibility, including:

temperature
humidity
days of the week
influenza epidemics
SARS epidemic

We use this information to determine the relationship between daily visibility and daily death counts. The output of this analysis gives us the <u>attributable</u>, (that is the <u>excess</u> or potentially <u>avoidable)</u>, deaths associated with each kilometre loss of visibility.

6	How far can we see on a clear day?	From our department in the medical school, on a clear day, the horizon would be at about 30 kilometres; Cheung Chau 11km, Lamma Island 3km.

The mean visibility during the last 24 months has been about 12.6km, a loss of 17.4km from a clear horizon; so how does that impact on the daily risk of dying in the SAR?

7	What is the annual mortality impact of visibility loss?	Here in the first column we have Observatory estimates of visibility; in the second column the estimated annualized deaths for a given loss of visibility and for comparison EPD monitored particulate levels for these different levels of visibility. At Hong Kong's average 12.6km mean visibility we estimate 1,200 avoidable deaths on average each year. Note that the WHO guideline is quite conservative; there is no threshold and we estimate that there are possible deaths at this level.

In the cool season the attributable daily death <u>rates</u> will be much higher on the typically <u>low visibility highly polluted</u> days in that period.

8	Hong Kong's Air Quality exceeds WHO safety limits	Why does Hong Kong have this serious environmental health problem? This slide summarises the evidence. First, we should note at EPD general monitoring stations our pollutants are 40% to 140% above WHO limits.

At the roadside stations we are 100% to 195% in excess of WHO minimum safety limits. These exceedances are a cost on current and future child health, the burden of heart and lung disease, premature deaths and health care costs.

9	Visibility and pollutants	We find that particulates and NO_2, which are signatures of traffic emissions, are strongly associated with our decline in visibility.

- Visibility is strongly negatively correlated with air pollution *especially Particulates (PM$_{10}$) and Nitrogen Dioxide (NO$_2$).*

- The higher the pollutant concentrations the lower the visibility.

- *PM$_{10}$ and NO$_2$ are strong signatures of traffic pollution*

10	The EPD approach to regulation ignores the WHO evidence base	The prospects for improved clarity in Hong Kong's vision, in the near future, are not encouraging. We suggest that EPD is ignoring the evidence on mortality risks by proposing to adopt extremely lax Air Quality Objectives. They could have chosen the WHO guideline or the WHO interim target 3 as their next objective, but instead defaulted to a much more lax limit and then corrupted it with additional allowable exceedances. It appears that the EPD proposes to only fit AQO's which they think they can achieve rather than recognize that effective health protection in our very polluted city requires much more stringent health based criteria. But if air pollution levels of this order are <u>allowed</u> and also <u>considered to comply with Hong Kong</u> (new) <u>air quality objectives</u> then we must also accept that we incur conservatively an additional (otherwise avoidable) 620 deaths annually, a total of at least 7,440 over a 12 year.

This image is based on average annual means but cool season levels are very much higher.

11	Cool season pollutant exposures are the highest	So, for 6 months of the year the population is exposed to much higher levels of pollution and cool season trends show no sign of converging with WHO limits or even with the proposed lax AQOs. We must insist on the analyses from an exposure and public health viewpoint including cool season roadside levels.
12		Hong Kong has the highest NO_2 levels of any comparably developed jurisdiction. Nitrogen dioxide trends are high and flat (ie no sign of improvement) at general stations; and rising sharply at the roadside. We have just reviewed

several recently published scientific articles on the harm caused by NO_2 to pregnant mothers, infants and children, and the risks of asthma and cancer. We might ask who in government is responsible for this important area of environmental risk assessment?

13   There are many reasons why we should care about loss of visibility. To these we can now add a pyramid of health effects:

deaths
hospital admissions
doctor visits
psychological impacts

and overall impairment of quality of life.

illness is associated with loss of productivity and education through work and school absenteeism.

and members will be aware of other concern about Hong Kong as a business centre and tourist destination.

14 A silent   So we suggest that our findings are important for several
    epidemic   reasons and here are two more:

First, the visibility – mortality relationship is a more valid health risk indicator than the current outdated government API.

Lack of   Second we need this approach to environmental
accountability   accountability because you will never hear the Environment Minister or Director EPD referring to our daily problem of pollution attributable deaths. The Food and Health Minister and Director of Health are held accountable for infectious disease outbreaks, but who is responsible, who is accountable for the massive epidemic of illness caused by pollution? Remember the deaths are only tip of the iceberg.

It is a "silent epidemic" and no one in government is formally responsible for estimating, recording and publishing pollution damage to population health in the HKSAR.

15   **<u>Need for a cohesive strategy</u>**

In this presentation we have been highly critical of EPD, and we regret having to take that position but forced to do so because EPD rejects WHO criteria as the explicit regulatory control measure. But equally, honorable members, we are aware that Legco rejects EPD proposals for controls on old polluting vehicles. While this is done on the grounds that it affects livelihoods we need to recognize that every polluting vehicle is a cause of impaired lung growth in children, illnesses and death across the population.

16   **<u>Conclusions</u>**

- Every kilometre reduction in visibility causes 70 additional deaths per year: a total of 1,200 in 2010..

- Visibility has *face validity* and *scientific validity* as a measure of health risks from pollution.

- We urge both government and Legco to adopt urgent, radical and effective measures to reduce local sources of pollutants.

Our analysis has clear implications for public health policy and is a call for immediate action to protect the health of Hong Kong.

Daily visibility and mortality: Assessment of health benefits from improved visibility in Hong Kong

Thuan-Quoc Thach [a], Chit-Ming Wong [a,*], King-Pan Chan [a], Yuen-Kwan Chau [a], Yat-Nork Chung [a], Chun-Quan Ou [b], Lin Yang [a], Anthony J. Hedley [a]

[a] School of Public Health, The University of Hong Kong, 5th Floor, Li Ka Shing Faculty of Medicine Building, 21 Sassoon Road, Hong Kong, China
[b] Department of Biostatistics, Southern Medical University, Guangzhou, China

A R T I C L E   I N F O

A B S T R A C T

Visibility in Hong Kong has deteriorated significantly over 40 years with visibility below 8 km in the absence of fog, mist, or precipitation, increasing from 6.6 days in 1968 to 54.1 days in 2007. We assessed the short-term mortality effects of daily loss of visibility. During 1996–2006, we obtained mortality data for non-accidental and cardiorespiratory causes, visibility recorded as visual range in kilometers, temperature, and relative humidity from an urban observatory, and concentrations of four criteria pollutants. A generalized additive Poisson regression model with penalized cubic regression splines was fitted to control for time variant covariates. For non-accidental mortality, an interquartile range (IQR) of 6.5 km decrease in visibility at lag 0–1 days was associated with an excess risk (ER%) [95% CI] of 1.13 [0.49, 1.76] for all ages and 1.37 [0.65, 2.09] for ages 65 years and over; for cardiovascular mortality of 1.31 [0.13, 2.49] for all ages, and 1.72 [0.44, 3.00] for ages 65 years and over; and for respiratory mortality of 1.92 [0.49, 3.35] for all ages and 1.76 [0.28, 3.25] for ages 65 years and over. The estimated ER% for daily mortality derived from both visibility and air pollutant data were comparable in terms of magnitude, lag pattern, and exposure–response relationships especially when using particulate matter with aerodynamic diameter $\leq 10\,\mu m$ to predict the mortality associated with visibility. Visibility provides a useful proxy for the assessment of environmental health risks from ambient air pollutants and a valid approach for the assessment of the public health impacts of air pollution and the benefits of air quality improvement measures in developing countries where pollutant monitoring data are scarce.

1. Introduction

Loss of visibility is an easily measured manifestation of air pollution, arising from a loss of contrast between the object and the background and attenuation of the light signal from the object due to scattering and absorption of light by fine particulates and gaseous pollutants (Sloane and White, 1986). In urban areas, it is regarded as a primary index of ambient air quality (Watson, 2002).

Visibility in Hong Kong has deteriorated significantly over 40 years and the number of days with visibility below 8 km in the absence of fog, mist, or precipitation has substantially increased from 6.6 days in 1968 to 54.1 days in 2007 (Hong Kong Observatory, 2009). Hong Kong is located in the Pearl River Delta region in southern China where increasing fossil fuel consumption has resulted in a rapid growth of anthropogenic emissions and thereby has led to an increase in air pollution and degradation in visibility (Streets and Waldhoff, 2000). This is attributed to increase in the concentrations of fine particulate matter ($PM_{2.5}$) and photochemical pollutants, which increase the scattering of light (Sequeira and Lai, 1998a; Ho et al., 2003).

In Hong Kong, ambient air pollution is associated with a wide range of adverse health effects in children and adults including respiratory illness (Peters et al., 1996), impaired lung function (Wong et al., 1998), increased consultations with physicians (Wong et al., 2002a), hospital admissions, and premature deaths from cardiopulmonary disease (Wong et al., 2001, 2002b, 2008a; Hedley et al., 2002), mostly at levels well below the currently adopted air quality objectives in Hong Kong (Hong Kong EPD,

2010). Air pollution has been identified as a major cause of increasing community costs due to health care utilization and lost productivity (Hedley et al., 2008). Previous studies, which assessed the association between fine particulates and mortality used various measures as indicators of air pollution, including coefficient of extinction, coefficient of haze, and airport visibility to estimate $PM_{2.5}$ and PM_{10} (Ozkaynak et al., 1985; Abbey et al., 1995; Ostro, 1995; Vajanapoom et al., 2001; Jerrett et al., 2004). However, apart from two studies, one showing that visibility loss was directly associated with sudden infant death syndrome in Taiwan (Knobel et al., 1995) and a second on the relationship between visibility and population mortality in Shanghai (Huang et al., 2009), no other reports have shown links between visibility and ill health or mortality. We aimed to assess the associations between variations in daily visibility and mortality in Hong Kong for the period 1996–2006 using several sensitivity analyses based on the mean visibility recorded at 10:00, 14:00, and 16:00 h, 24 h maximum visibility, different cut-off limits for humidity, and adjustments for air pollutants.

2. Materials and methods

2.1. Mortality

Daily mortality data for the eleven year period from January 1996 to December 2006 were obtained from the Hong Kong Census and Statistics Department including date of death and underlying cause of death coded according to the International Classification of Diseases, ninth revision (ICD-9) or tenth revision (ICD-10). The main health outcome of this study comprised all known non-accidental deaths of Hong Kong residents (ICD-9:1-799; ICD-10: A00-R99), as well as cardiovascular (ICD-9:390-459; ICD-10:I00-I99), respiratory (ICD-9:460-519; ICD-10:J00-J98), and accidental mortalities (ICD-9: 800-999; ICD-10: S00-T98). We chose two age groups for analyses: all ages and a subgroup aged 65 years and over. An assessment of the discrepancy between the classification of causes of deaths using ICD-9 and ICD-10 showed that agreement between the two coding systems was over 90% (Hong Kong Department of Health, 2005).

2.2. Visibility and meteorological conditions

For the period 1996–2006, visibility data measured at the Hong Kong Observatory were recorded as the visual range in kilometers. The hourly observations of horizontal visibility were made by naked eye from 0:00 to 23:00 h by specially trained observers using suitable targets at various distances in accordance with procedures established by the World Meteorological Organization guidelines (Pueschel, 1983; World Meteorological Organization, 2010). Visibility observations were averaged to provide 24 hour mean visibility. Hourly meteorological conditions were also available at the Hong Kong Observatory including mean temperature in Celsius and mean relative humidity in percent. There were no missing visibility and meteorological observations during the period of study. The average numbers of hazy days were estimated by the hourly visibility and humidity data. They were calculated by the annual proportion of hours with visibility ⩽ 8 km and humidity ⩽ 80%, and then multiplied by 365 or 366 days.

2.3. Concentrations of air pollutants

Air pollutant data from the Environmental Protection Department's eight monitoring stations included daily 24 h average concentrations of particulate matter with aerodynamic diameter ⩽ 10 μm (PM_{10}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and 8 hour (10:00–18:00 hours) mean concentrations of ozone (O_3). Measurements of PM_{10}, NO_2, SO_2 and O_3 were, respectively, made by tapered element oscillating microbalance (TEOM), chemiluminescence, fluorescence, and ultra violet absorption. Daily concentrations were valid if more than 17/24 h or 5/8 h (in the case of O_3) were available (US EPA, 1999; Wong et al. 2008a). The eight monitoring stations considered in this study are stations situated at an average of 20 m above ground level with no roadside stations included. Concentrations of pollutants from all stations providing data were averaged to provide daily estimates across the city. There were no missing values for the four pollutants during the period of study.

2.4. Statistical analysis

We developed core models with a generalized additive Poisson regression allowing for over-dispersion in the model (Wood, 2006). For each mortality outcome, variations in seasonality, trends, mean temperature, and mean humidity of current and previous days (lag 0–1) were fitted with penalized cubic regression splines. Dummy variables were used to control the variations for days of the week, holidays, and influenza epidemics. We added a dummy variable for the 2003 severe acute respiratory syndrome (SARS) epidemic. We chose 4 degrees of freedom (df) per year for smoothing function of the trends and 3 df for temperature and humidity. The choice of df for each smoothing function in the core models was made on the basis of observed residual autocorrelations using partial autocorrelation function (PACF). For the core models fitted to the mortality data, time variant confounding factors were considered as adequately controlled if absolute values of PACF coefficients were < 0.1 for the first two lag days and there were no systematic patterns in the PACF plots (Wong et al., 2008a).

Following the construction of an adequate core model for each mortality outcome, we entered visibility as a linear term into the regression model and examined the effects of visibility on mortality for single day lags 0–5 days, lag 0–1, and distributed lag 0–4 days (Schwartz, 2000; Zanobetti et al., 2000). The distributed lag effect take into account the possibility that visibility can affect deaths occurring on the same day and on several subsequent days. The net effect of visibility was the sum of the effect estimates for all six days. We expressed the effect of visibility as the percentage change in daily mortality with a decrease in the interquartile range (IQR) of visibility as $100\% \times IQR \times \beta$, where β is the estimated Poisson regression coefficient, and referred to as the excess risk (ER%).

We conducted sensitivity analyses to examine the robustness of the effect estimates for non-accidental mortality at all ages as follows:

1. *Degrees of freedom for trends*: using 3 and 5 df per year for smoothing the time trends in the core model.
2. *Exclusion of visibility with cut-off limit for humidity*: we screened hourly visibility readings and excluded those associated with humidity > 80% or > 90% or wet conditions including fog, mist, and precipitation and calculated 24 h mean visibility on this basis.
3. *Metric used for visibility*: We used the mean visibility based on the three measurements recorded at 10:00, 14:00, and 16:00 hours, and the 24 h maximum visibility in place of 24 h mean visibility.
4. *Exclusion of extreme visibility range*: we excluded readings of visibility less than 8 km; less than the 25th percentile; or less than the 5th percentile of visibility, by regarding them as missing.
5. *Adjustment for air pollutants*: we adjusted for each of the four pollutants PM_{10}, NO_2, O_3, or SO_2 in turn at lag 0–1 in the models.
6. *Average lag 0–2 days for temperature and humidity*: we substituted average of current day and previous two days (lag 0–2 days) for temperature and humidity in the core models in place of lag 0–1 days.
7. *Natural cubic regression splines*: We fitted natural cubic regression splines in place of penalized cubic regression splines.

All analyses were performed using the statistical software package R version 2.9.1 (R Development Core team, 2009) with mgcv package version 1.5-5.

3. Results

3.1. Mortality, visibility, air pollutants, and meteorology

There were about 360,000 deaths during the period of study. For non-accidental mortality, the number of daily deaths at all ages ranged from 48 to 153 per day; 6 to 56 for cardiovascular mortality, and 3 to 41 for respiratory mortality. Air pollutant mean values in μgm^{-3} were PM_{10}: 53.7; NO_2: 59.0; O_3: 38.4; and SO_2: 19.6 (Table 1). The Spearman correlations between pollutants were positive ranging from $r=0.29$ to 0.80, with the exception of the correlation between O_3 and SO_2 ($r=-0.06$).

The average number of hazy days per year increased from 6 days in 1970 to 32 days in 2006 (Fig. 1). Mean visibility (13.3 km) was higher than the median (12.4 km), indicating the distribution was mildly positively skewed (Table 1). The Spearman correlations between daily visibility and the concentrations of the four pollutants were negative ranging from $r=-0.64$ to -0.04. The Spearman correlations were high between visibility and PM_{10} ($r=-0.64$) and NO_2 ($r=-0.54$) and low between visibility and O_3 ($r=-0.23$) and SO_2 ($r=-0.04$).

Table 1
Distribution of daily visibility, mortality counts, and meteorological measurements in Hong Kong, 1996–2006 (N=4018 days).

	Mean	SD	Percentiles					IQR
			Min	25th	50th	75th	Max	
Visibility[a] (km)	13.3	5.3	1.2	9.6	12.4	16.1	31.3	6.5
Pollutant ($\mu g\,m^{-3}$)								
PM_{10}	53.7	27.0	13.7	32.4	47.9	69.9	210.7	37.5
NO_2	59.0	20.8	10.3	44.8	56.5	70.4	169.0	25.6
O_3	38.4	24.3	0.7	19.3	32.7	53.1	195.0	33.8
SO_2	19.6	14.1	1.4	10.4	16.0	24.4	143.5	14.0
Temperatures (°C)	23.6	5.0	6.9	19.6	24.8	27.7	31.8	8.1
Humidity (%)	78.1	9.9	27.5	73.6	79.3	84.7	98.1	11.0
Non-accidental								
All ages	89.0	14.4	48.0	79.0	88.0	98.0	153.0	19.0
Ages ≥ 65 years	69.9	13.4	35.0	60.0	68.0	78.0	131.0	18.0
Cardiovascular								
All ages	24.8	6.8	6.0	20.0	24.0	29.0	56.0	9.0
Ages ≥ 65 years	21.2	6.3	3.0	17.0	21.0	25.0	50.0	8.0
Respiratory								
All ages	16.8	5.4	3.0	13.0	16.0	20.0	41.0	7.0
Ages ≥ 65 years	15.4	5.1	3.0	12.0	15.0	18.0	38.0	6.0
Accidental								
All ages	4.3	2.3	0.0	3.0	4.0	6.0	14.0	3.0
Ages ≥ 65 years	1.4	1.2	0.0	1.0	1.0	2.0	8.0	1.0

[a] The visibility is based on the 24 h mean at lag 0–1 days. Higher values of visibility correspond to better visibility. *Abbreviations*: IQR: interquartile range, Min: minimum; Max: maximum; SD: standard deviation.
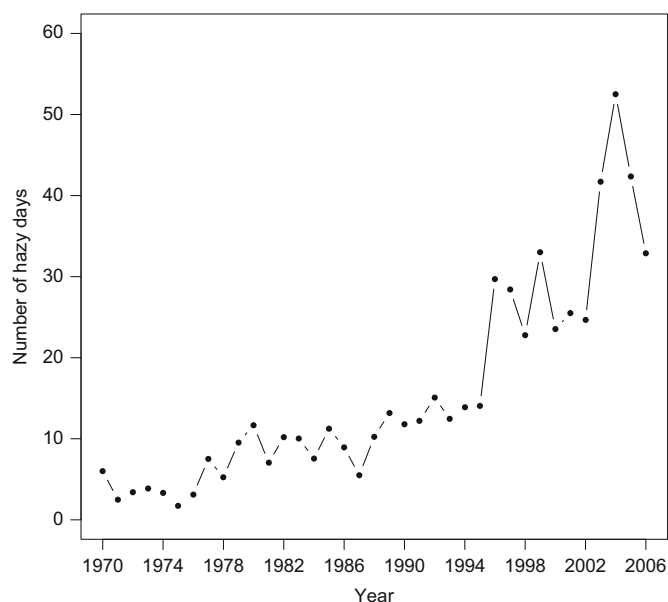

Fig. 1. The average number of hazy days for each year defined according to the proportion of hours with visibility ≤ 8 km and relative humidity ≤ 80% observed at the Hong Kong Observatory, 1970–2006.

Visibility increased with temperature ($r=0.47$), but the correlation between visibility and humidity was low ($r=-0.17$).

Concentrations of pollutants were generally highly correlated with monitoring stations. The ranges of Spearman correlations for concentrations of the four pollutants at eight monitoring stations were PM_{10}: $r=0.91–0.97$, NO_2: $r=0.67–0.92$, O_3: $r=0.62–0.89$, and SO_2: $r=0.46–0.83$ (data not shown). The means and standard deviations (SD) for the four pollutants in $\mu g\,m^{-3}$ were, for PM_{10}: 50.1–59.6 (SD: 26.5–32.8), NO_2: 46.8–69.0 (SD: 20.9–23.6),

O_3: 27.5–56.3 (SD: 21.5–29.7) and, SO_2: 15.0–25.1 (SD: 12.7–20.6) (data not shown). Humidity and visibility exhibited a marked seasonal variation with humidity highest in the warm season, but with visibility lowest in the cool season (October–March) and highest in the warm season (April–September), corresponding to the zenith and nadir of the annual seasonal pattern of concentrations for PM_{10}, NO_2, and O_3 (data not shown).

3.2. Lag effect of visibility

We report the results using lag 0, lag 0–1, and the distributed lag for lag 0–4 days for an IQR (6.5 km) decrease in visibility. The largest effect at lag 0–4 was estimated for respiratory mortality followed by cardiovascular and non-accidental mortalities, ranging from 1.13 to 1.92 with ER% all statistically significant. The effects for the distributed lag 0–4 days were lower than for lag 0 and lag 0–1, with estimates ranging from −0.04 to 1.99 except for the respiratory mortality, which showed stronger effects. No statistically significant associations were found with accidental mortality (Table 2). The lag pattern of the visibility effects was similar to PM_{10} with maximum effect at lag 0–1 for both visibility and PM_{10} (data not shown). The effect estimates of visibility were sensitive to lag specifications (Fig. 2).

3.3. Sensitivity analyses

We report the results of sensitivity analyses only for non-accidental mortality at all ages. In general, the effect estimates were statistically significant for all analyses with the exception of adjustments for air pollutants, which resulted in non-significant effect estimates. The effect estimates, which ranged from 0.91 to 1.18 were reduced by less than 20% from those in the main analysis, when we changed degrees of freedom for trends, excluded visibility observations with a cut-off limits for humidity > 90%, excluded visibility observations falling below the 5th percentile, fitted average lag 0–2 days for temperature and humidity, and used natural cubic regression splines for smoothing. However, in other cases the effect estimates were reduced by more than 20%, ranging from 0.65 to 0.90 (Table 3). The full set of results on other mortality outcomes is available in the Supplementary Material.

4. Discussion

In Hong Kong's heavily polluted environment, we found that a decrease in visibility at lag 0–1 days was associated with increase in daily mortality, which was the largest for respiratory mortality followed by cardiovascular mortality and all non-accidental mortality. We found that the visibility effect estimates for mortality were comparable to those derived from specific air pollutants with respect to the magnitude, lag pattern, and the shape of exposure–response curves especially compared to the results derived from PM_{10} concentrations. The strongest association between visibility and mortality was for respiratory causes. In Hong Kong, fine particulate matter was the main contributor to the reduction in visibility with ammonium sulfate from regional sources being the largest component (51%) (Wang, 2003) and based on our limited data on $PM_{2.5}$ for one station from 1998 to 2006, the Spearman correlation between visibility and $PM_{2.5}$ was −0.78 (data not shown). This high correlation suggests that the use of the visual range as a measure of fine respirable particulates is a good proxy for estimating the effects of combustion particulates on mortality outcomes. The strongest effects on mortality were those associated with NO_2 concentrations (data not shown), consistent with our previous analyses (Wong et al.

Table 2
Estimated excess risks (ER%) for daily mortality and associated 95% confidence intervals (CI) per interquartile range decrease in visibility (6.5 km) under different lag models.

|	Models					
	Lag 0		Lag 0–1		Distributed lag (lag 0–4)	
	ER%	95% CI	ER%	95% CI	ER%	95% CI
Non-accidental						
All ages	0.92	0.38 to 1.47	1.13	0.49 to 1.76	−0.04	−0.90 to 0.81
Ages ≥ 65 years	1.21	0.59 to 1.83	1.37	0.65 to 2.09	0.21	−0.76 to 1.18
Cardiovascular						
All ages	1.21	0.20 to 2.22	1.31	0.13 to 2.49	−0.09	−1.67 to 1.49
Ages ≥ 65 years	1.55	0.45 to 2.65	1.72	0.44 to 3.00	0.42	−1.30 to 2.13
Respiratory						
All ages	1.19	−0.05 to 2.42	1.92	0.49 to 3.35	1.99	0.09 to 3.90
Ages ≥ 65 years	1.18	−0.10 to 2.47	1.76	0.28 to 3.25	1.88	−0.11 to 3.86
Accidental						
All ages	0.48	−1.96 to 2.93	0.43	−2.39 to 3.26	2.64	−1.08 to 6.35
Ages ≥ 65 years	0.13	−3.93 to 4.19	−0.49	−5.10 to 4.13	−3.41	−9.27 to 2.43
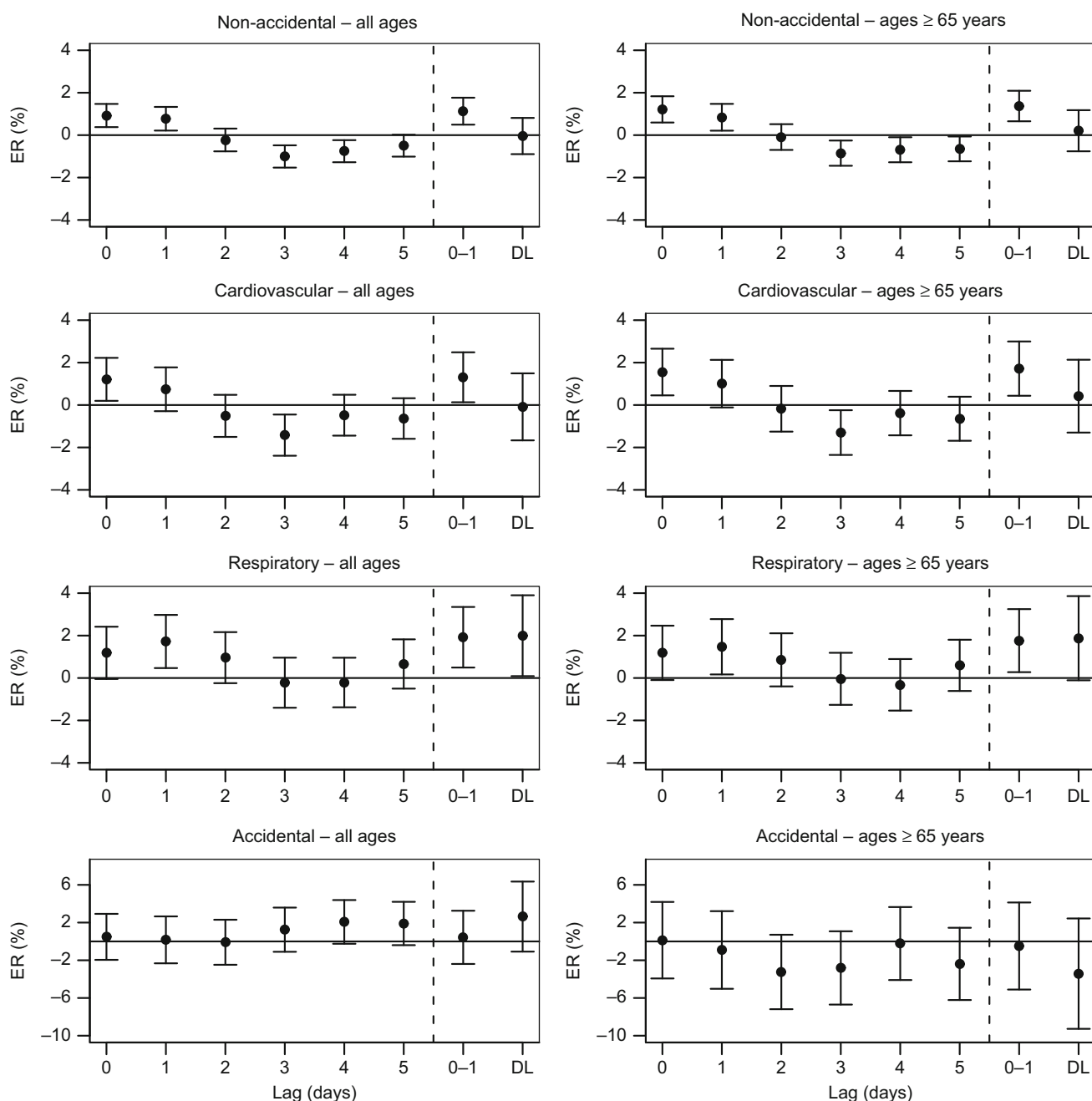
Fig. 2. Estimated excess risks (ER%) for daily mortality and associated 95% confidence intervals per interquartile range decrease in visibility (6.5 km) at single lags 0–5, mean lag 0–1 (0–1) and distributed lag (DL) for lag 0–4 days.

Table 3
Estimated excess risks (ER%) for daily mortality and associated 95% confidence intervals (CI) per interquartile range decease in visibility (6.5 km) at lag 0–1days for non-accidental mortality at all ages compared with sensitivity analyses.

	ER%	95% CI
Main analysis with 4 degrees of freedom for trends per year	1.13	0.49 to 1.76
1. Degrees of freedom for trends		
a. 5	0.92	0.29 to 1.54
b. 3	0.92	0.30 to 1.55
2. Exclusion of visibility with cut-off limit for humidity (%)		
a. > 90	1.11	0.49 to 1.73
b. > 80	[0.70]	0.08 to 1.33
3. Metric used for visibility		
a. Mean based on the three measurements recorded at 10:00, 14:00 and 16:00 h	[0.72]	0.19 to 1.24
b. 24 h maximum	[0.90]	0.40 to 1.39
4. Exclusion of extreme visibility range		
a. < 8 km	[0.85]	0.11 to 1.58
b. < The 25th percentile	[0.86]	1.70 to 0.02
c. < The 5th percentile	0.91	0.24 to 1.58
5. Adjustment for air pollutants		
a. PM_{10}	[0.65]	− 1.57 to 0.27
b. NO_2	[0.43]	− 0.29 to 1.15
c. O_3	[0.83]	0.11 to 1.55
d. SO_2	[0.65]	− 0.02 to 1.31
6. Average lag 0–2 days for temperature and humidity	1.18	0.56 to 1.80
7. Natural cubic regression splines	1.14	0.49 to 1.78

Note: ER% in squared brackets when it changed > 20% from the main analysis.

2008a). It is noteworthy that PM_{10} was strongly correlated with other pollutants, particularly with NO_2, and the strong PM_{10} correlation with NO_2 may have contributed to the ability to detect the effects of visibility on mortality.

The size of the effects and the cause-specific pattern of mortality indicate that some susceptible groups in the population may benefit more from improvements in the visibility range particularly among individuals with cardiovascular and respiratory diseases. The linear effect seen in all mortality outcomes and age groups suggests that there is no clear threshold value and the effect estimates from this study are consistent with a linear model without threshold for PM_{10} demonstrated in studies from Asia, West Europe, and North America (Daniels et al., 2000; Samoli et al., 2006; Pope and Dockery, 2006; Wong et al., 2008a). Further evidence on linear relationships between daily visibility and daily deaths in vulnerable subgroups, compared to the general population, would be provided by further cohort studies with both short- and long-term outcomes.

It is well recognized that meteorological conditions, in particular humidity, are strong determinants of visibility in urban settings. Malm and Day (2001) examined the association between reduction in visibility and humidity in the United States and argued that at 90% humidity the light scattering cross-section of ammonium sulfate particles may be increased by a factor of five or more times above that of dry particles. Sequeira and Lai (1998b) suggested a cut-off limit of 80% in humidity for assessing the visibility in Hong Kong, which lies close to the coast. This limit might remove measurements in which high levels of particulate matter were also associated with high humidity conditions; however, sensitivity analyses with these more stringent cut-off limits and excluding periods of fog and precipitation have not significantly affected our estimates of associations between visibility and mortality. They did not alter the conclusion that improved visibility leads to health benefits and that the estimation of low visibility is an effective surrogate for air pollutants in this region.

Previous studies on atmospheric visibility, including the estimation of fine particulates, suggested that midday visibility values were appropriate measures. They are more representative of regional visibility levels because daytime and nighttime visibilities are often incompatible and early morning fogs and high humidity, which may affect local conditions, are dispersed by midday (Ozkaynak et al., 1985; Abbey et al., 1995). Sensitivity analyses showed that different measures of visibility such as taking the mean visibility based on the three measurements recorded at 10:00, 14:00, and 16:00 h led to substantial decreases in the estimates by more than 20% compared to those from 24 h mean visibility. We used 24 h mean visibility, which yielded the mortality effect estimates most comparable to those derived from air pollutants.

Reduction in daily visibility is a widespread and increasing problem associated with deterioration in air quality in many East Asian and South Asian countries (Wang et al., 2009). One major problem has been the inadequate data on the ambient mass concentrations of the criteria air pollutants, but good visibility measurements are routinely recorded at most meteorological stations and at airfields, and often available over several years. In the absence of air pollutant data, the use of visibility measures can be deployed quickly by environmental health authorities for estimating the health effects of air pollution including the shape of exposure–response curves for mortality. This locally generated evidence can provide important support for public health through air quality improvement policies, particularly because of its potential to protect the health of susceptible subgroups in the population, including those who are socioeconomically deprived (Ou et al., 2008; Wong et al., 2008b).

4.1. Study strengths and limitations

Our study has several unique features. It covered eleven years of data with a large sample size of about 360,000 deaths and had high statistical power to detect significant associations in visibility associated mortality. The analytic method used in this study follows the current standard approach adopted in the assessment the of short-term effects of air pollution on mortality in daily time series studies (Samet et al., 2000). An important feature of this method is that the likelihood of confounding effects

of visibility is minimized by removing other factors, which may be associated with variations in mortality. Once the core models were determined, visibility was entered to identify associations between visibility and mortality. So all potential observable time variant and unobservable confounding effects would have been reduced. Our data on visibility, air pollutants, mortality, and meteorology are reliable in that they have undergone rigorous quality control procedures performed independently by several government departments.

Some limitations were present in our study. First, even though our conclusion has internal consistency, it needs to be replicated in other jurisdictions because of different methodologies, which may be adopted for visibility and air pollutant measurements and the properties of air pollutant mixtures, which, especially for particulates, could be different from Hong Kong. Second, it must include recognition that visibility observations are surrogate measures of pollutants and not a measure of exposure, and that they could be misclassified because of the inherently subjective nature of visibility measurements, but these errors would ultimately bias the outcomes towards the null effect. Finally, as in all time series studies, data on mortality and covariates are collected at the aggregated level and caution should be exercised in drawing a causal association between the underlying effects of poor visibility and mortality.

5. Conclusions

The use of validated and robust methods suggests that decreased visibility was associated with increased risk for non-accidental, cardiovascular, and respiratory mortalities. Visibility measures, with face validity, can provide a useful tool for environmental health impact assessment in regions where air pollutant monitoring data are limited or absent. There is scope for further research to elucidate the role of visibility in the assessment of health effects associated with air pollution. From a public health viewpoint, our findings provide an effective means to support the development of risk perception and to communicate to policy makers, government officials, law makers, the general public and the media, the relevance of poor visibility to impaired quality of life, lost productivity, and environmental health problems.

Acknowledgments

Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envres.2010.05.005.

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立法會 發佈：二零一一年一月廿八日

我們的健康 與 環境

香港能見度降低是否有損健康?

環境健康研究組

香港大學
公共衛生學院
社會醫學系

能見度降低可否作為社區嚴重健康問題的指標？
一項新的分析

Daily visibility and mortality: Assessment of health benefits from improved visibility in Hong Kong

Thuan-Quoc Thach[a], Chit-Ming Wong[a,*], King-Pan Chan[a], Yuen-Kwan Chau[a], Yat-Nork Chung[a], Chun-Quan Ou[b], Lin Yang[a], Anthony J. Hedley[a]

[a] School of Public Health, The University of Hong Kong, 5th Floor, Li Ka Shing Faculty of Medicine Building, 21 Sassoon Road, Hong Kong, China
[b] Department of Biostatistics, Southern Medical University, Guangzhou, China

你能看見到你所呼吸的空氣…

尖沙咀眺望維多利亞港

能見度較高

能見度較低

來源：Ed Stokes. 香港自然環境攝影基金會

近年香港能見度有什麼變化?

每年煙霞
日數

能見度低於8公里及濕度低於
80%的煙霞天氣的日數

年份

有否察覺到一個長期流行病的出現?

來源: 香港天文台

能見度 – 死亡人數模型

輸入　　　　　　　　　　分析　　　　　輸出

每日能見度 (公里)

\+

溫度 (ºC)

\+

濕度 (%)

\+

星期 (一至日)

\+

流感

\+

SARS

每日死亡人數

=
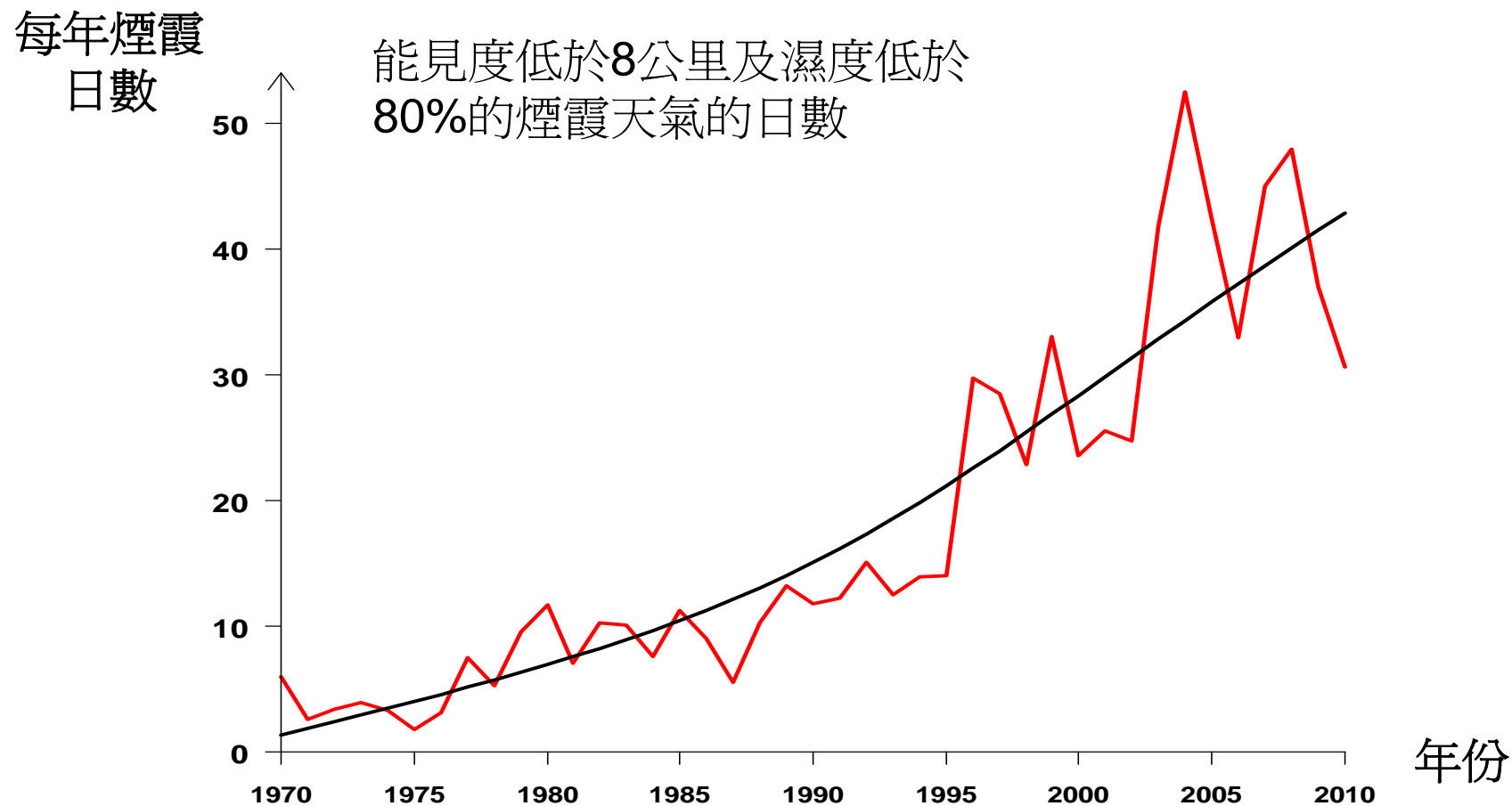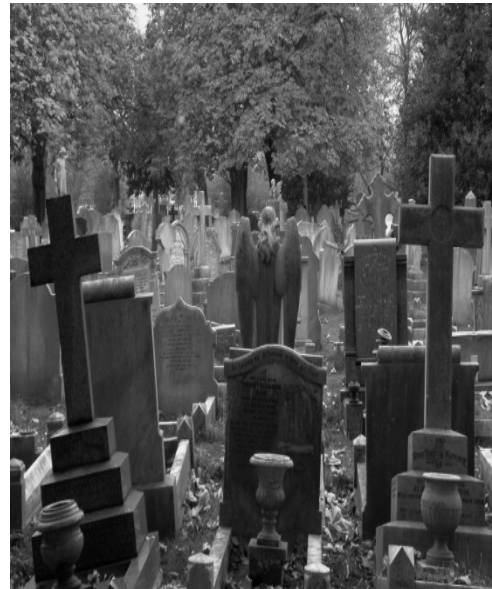
能見度每降低1公里相關死亡增加的百分比

在晴朗的日子我們可以看多遠？

平均能見度 ＝ 12.6km

能見度低 ＝ 30km – 12.6km = 17.4km

能見度低對每年死亡人數有何影響?

PM$_{10}$: 26 µg/m³
(能見度: 21 km)

香港仔

PM$_{10}$: 144 µg/m³
(能見度: 5 km)

能見度（公里）	每年相關死亡人數	懸浮粒子(µg/m³)
30 地平線	0	可忽略
24	420	20
21	625	30
15	1040	50
12.6	1200	
9	1460	70
5 or lower	1740+	84+
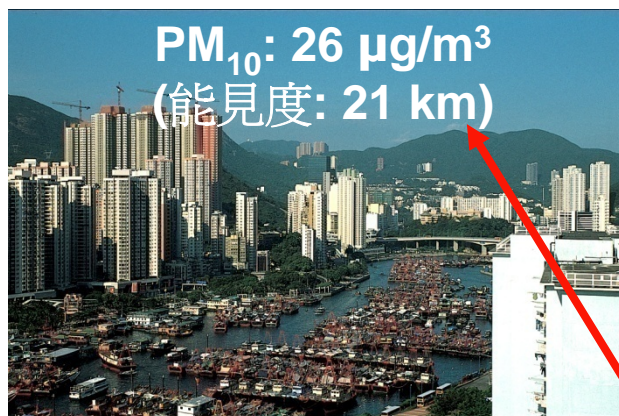
PM$_{10}$濃度符合世界衛生組織（WHO）空氣質素指引年均標準

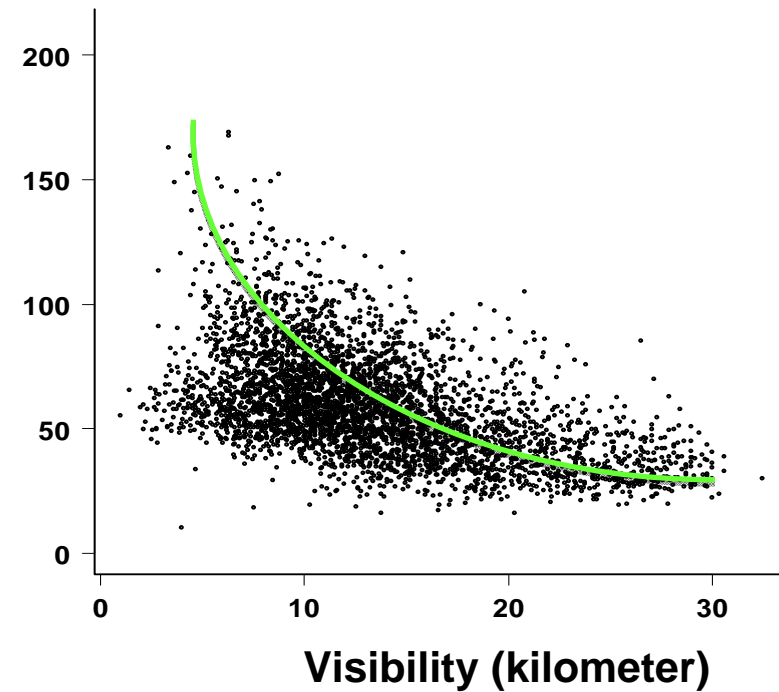PM$_{10}$濃度超過WHO空氣質素指引年均標準

香港空氣質素
我們的空氣污染物濃度高於
世界衛生組織最低安全標準多少?

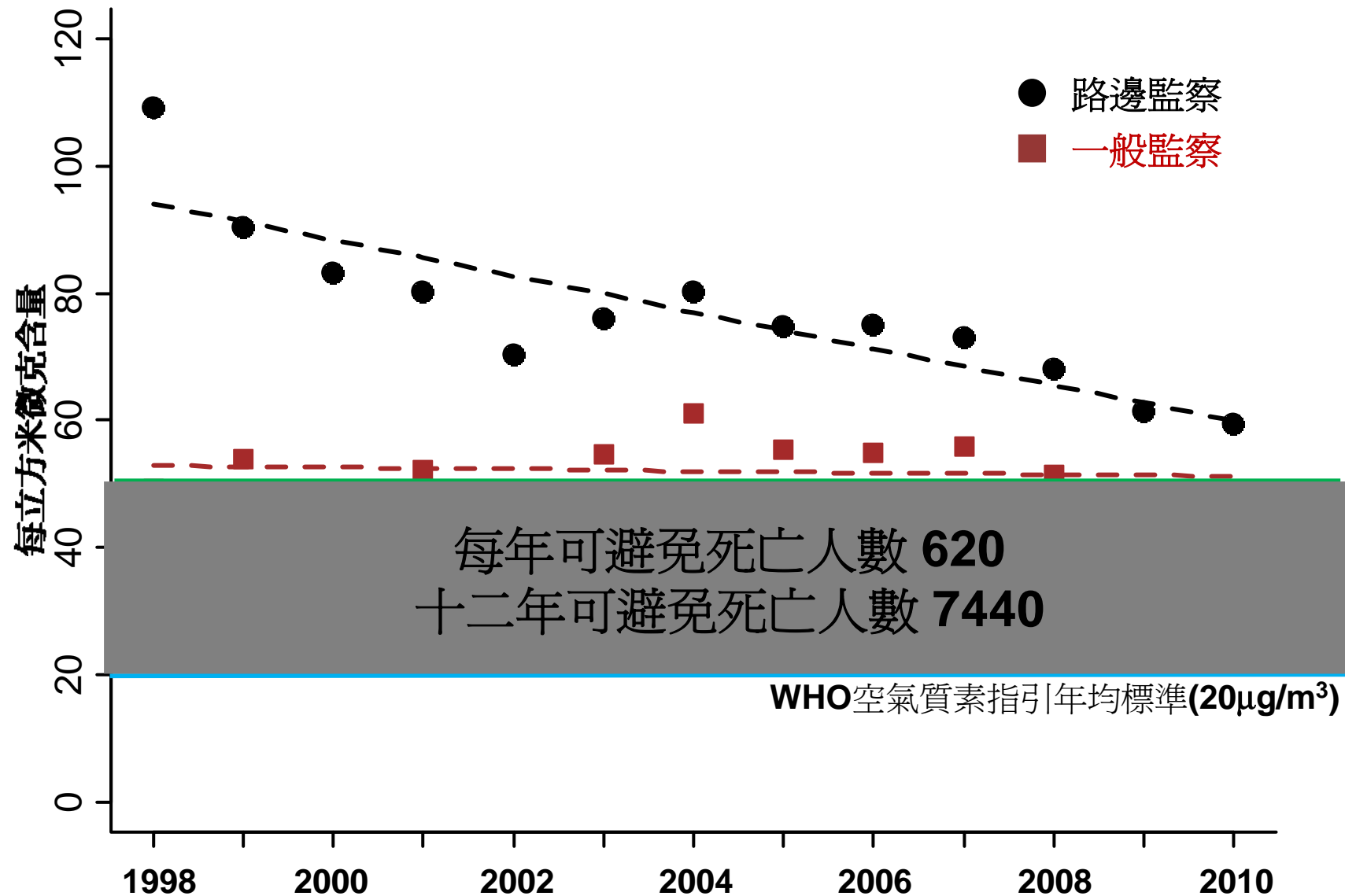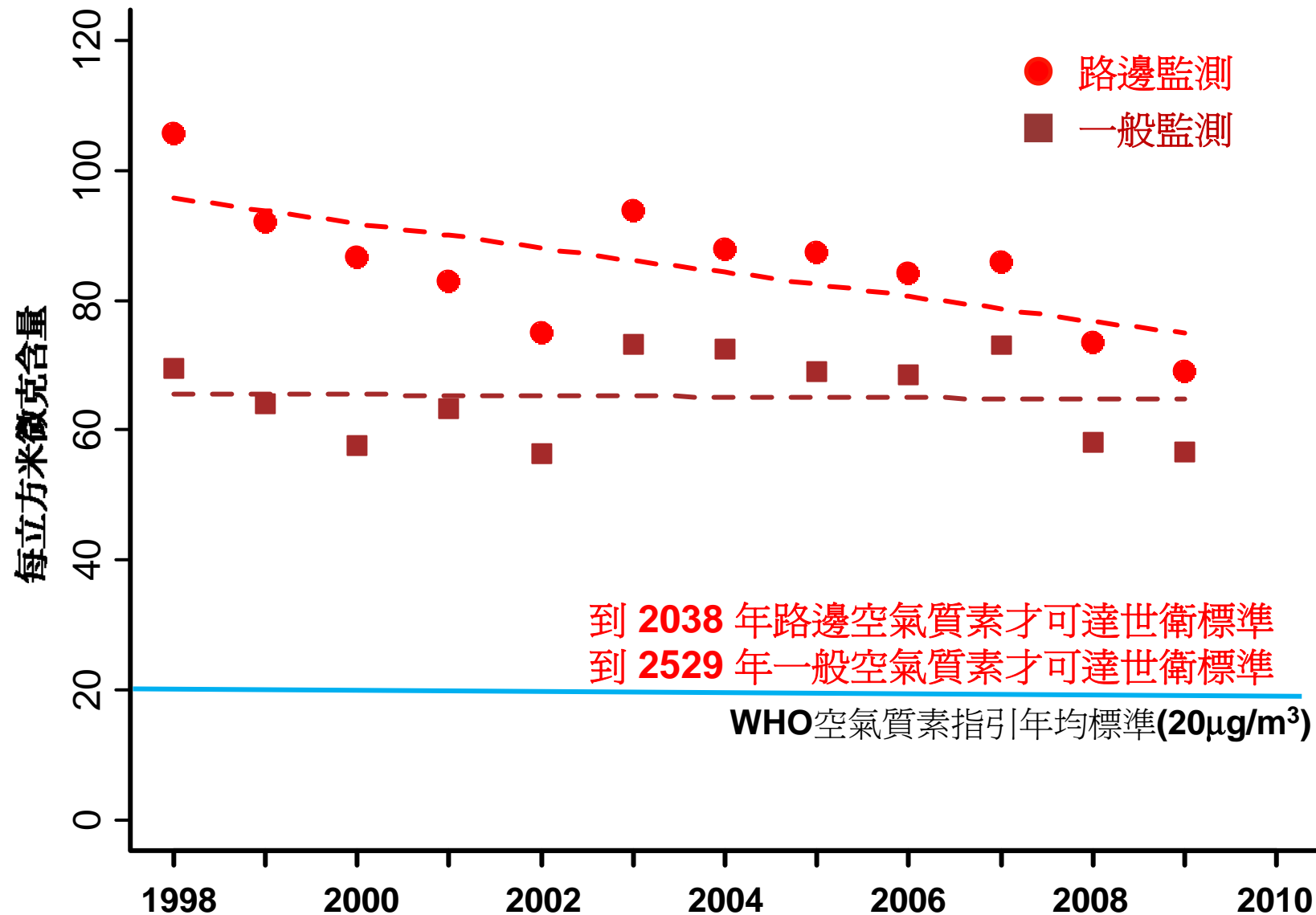|	% 高過世界衛生組織標準	
	一般監測	路邊監測
懸浮粒子	125%	195%
二氧化氮	40%	195%
二氧化硫	140%	100%

什麼是造成能見度低的主要原因？

懸浮粒子 *(PM$_{10}$)*
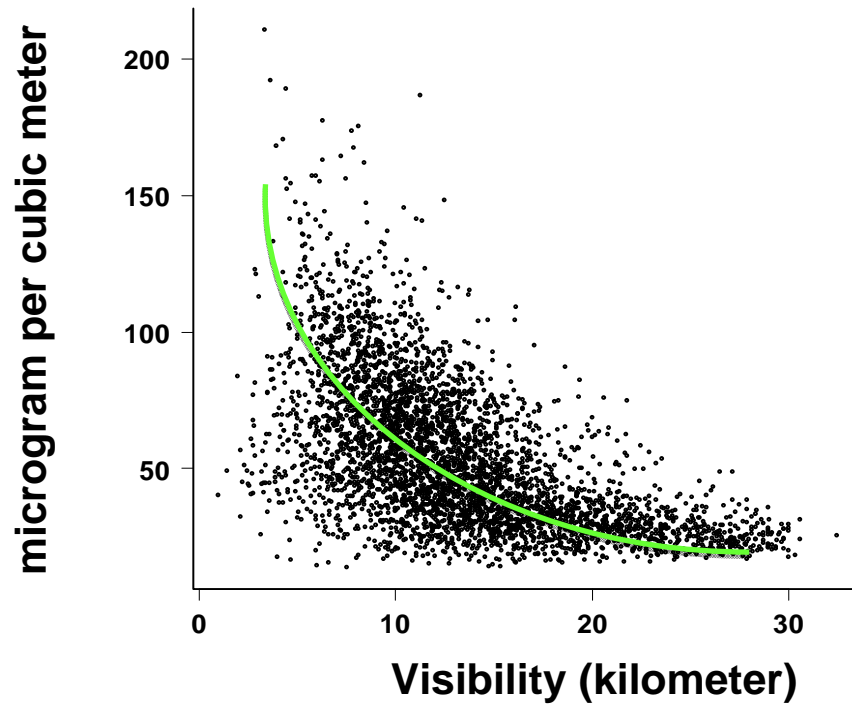
二氧化氮 *(NO$_2$)*

- 能見度與空氣污染為負相關，尤其是與*懸浮粒子(PM$_{10}$)及二氧化氮(NO$_2$)*為甚
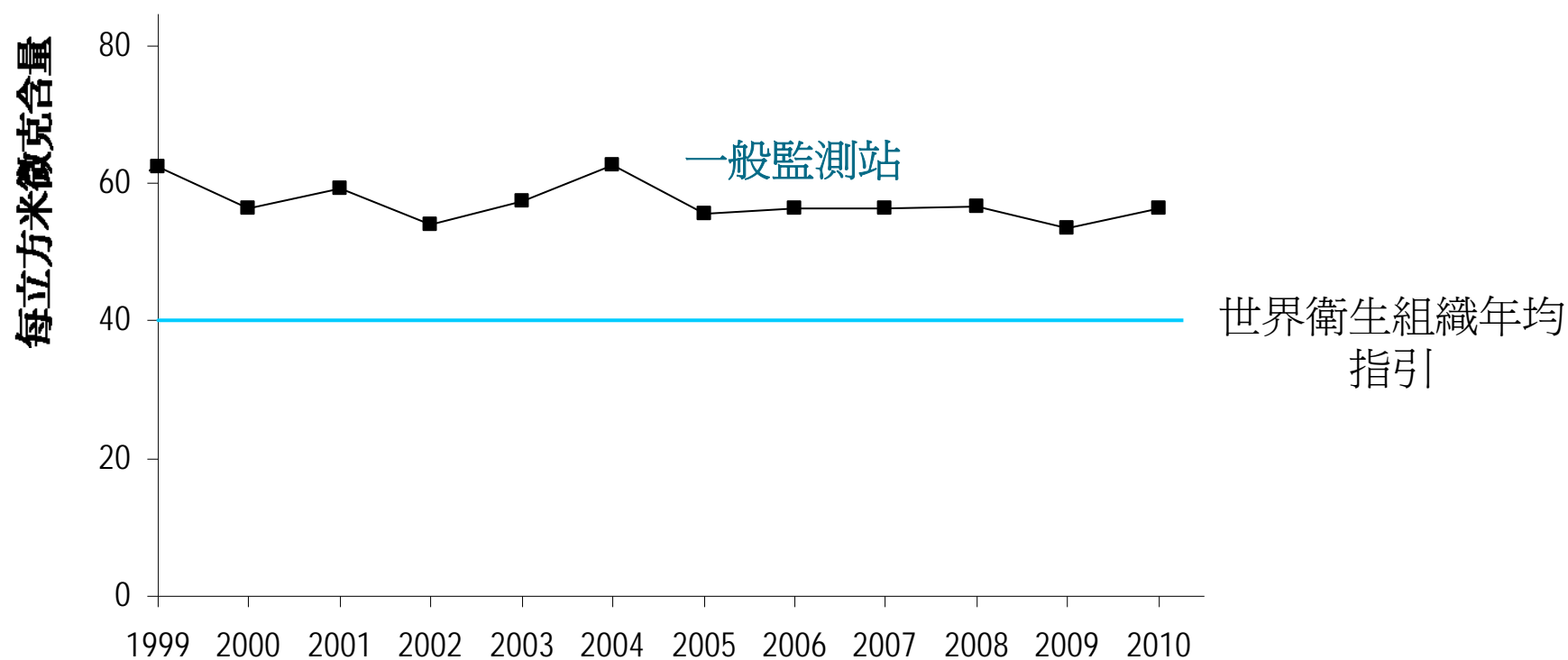- 污染物濃度越高，能見度越低
- PM$_{10}$及 NO$_2$均為交通工具產生的主要污染物

懸浮粒子：**1998 - 2010**

每年可避免死亡人數 **620**
十二年可避免死亡人數 **7440**

WHO空氣質素指引年均標準**(20μg/m³)**

● 路邊監察
■ 一般監察

每立方米微克含量

懸浮粒子：天氣較冷時段 1998 - 2010

- ● 路邊監測
- ■ 一般監測

到 2038 年路邊空氣質素才可達世衛標準
到 2529 年一般空氣質素才可達世衛標準

WHO空氣質素指引年均標準(20μg/m³)

每立方米微克含量

一般監測站的NO$_2$年均濃度

爲什麼我們需要關注能見度降低?

健康因素
死亡率
住院率
醫療成本
心理影響

生活質素

降低生產力
員工及學生的病假

商業投資

旅遊業 – 無吸引力的旅遊點
城市品牌

無聲的流行病：
問責的需要

能見度及相關的死亡人數
作為危害健康指標，比政
府制訂的「空氣污染指
數」更為真確

*殮房內的屍體標籤
不會標注
「死於空氣污染」*

能見度
降低

我們需要有凝聚力的策略

- 但是環保署拒絕引用世界衛生組織的空氣質素指引

- 立法會拒絕環保署提出管制產生污染的舊車輛的建議

總結

- 能見度每下降一公里香港死亡人數每年增加70人；2010年度總額外死亡人數為1,200人。

- 能見度可作為空氣污染損害健康的指標。

- 我們敦促政府和立法會緊急制訂徹底和有效措施減少本地空氣污染源頭。

我們的分析對公共衛生政策有明顯的作用。
現呼籲立刻採取行動保護香港市民健康。

- News

Hong Kong's murky skyline is linked with excess deaths

1. **Jane Parry**

+ Author Affiliations

1. [1]Hong Kong

Hong Kong's air pollution is associated with 1200 excess deaths a year in the city, say researchers at the University of Hong Kong. For every 6.5 km reduction in visibility from a clear horizon of 30 km there is a 1.13% rise in all non-accidental causes of death, they say.

Anthony Hedley, the study's principal researcher and honorary professor of the university's School of Public Health and its Li Ka Shing Faculty of Medicine, said, "Visibility is now the most dominant feature of Hong Kong's environmental air quality problem, with serious implications for health, economic activities, and the overall status and brand value of the [territory]."

The study is one of the first of its kind to use visibility data to assess the effects on health of pollution, a method that can easily be replicated in other locations, the authors say.

The research combined 4018 days' worth of visibility measurements from 1996 to 2006 and air pollutant data on particulate matter with aerodynamic diameter ≤10 micrometres (PM_{10}), nitrogen dioxide, sulphur dioxide, and 8 hour mean concentrations of ozone. These data were combined with death rates and causes of death, particularly cardiovascular, respiratory, and accidental deaths.

The researchers then used Poisson regression analysis to calculate the association between visibility and excess deaths with a lag of 0, 0-1, and 0-4 days, taking into account temperature, humidity, day of the week, and the epidemics of flu and severe acute respiratory syndrome that occurred during the study period.

Thach Thuan-quoc, honorary assistant professor at the School of Public Health, said, "The majority of the additional avoidable deaths were due to respiratory and cardiovascular disease."

The findings were published in *Environmental Research* in August last year (2010;110:617-23, doi:10.1016/j.envres.2010.05.005), but the research team waited until the winter, when Hong Kong's pollution is at its highest, to publicise the findings. Professor Hedley said, "There is a marked U shaped curve in seasonal pollutants, and it's in the winter when the biggest hit to people's health is happening."

The association between impaired visibility, suspended particulates, and greater mortality is accepted by the Hong Kong government, but using visibility as a measure is not in itself particularly useful, said a spokeswoman for Hong Kong's Environmental Protection Department. "The use of visibility would only be a surrogate for air pollution in an absence of air pollutant data. That is, however, not the case in Hong Kong," she said.

But Professor Hedley maintains that visibility is an easy measure for the lay person to understand and can also be used in places without sophisticated air quality monitoring.

"It makes it easier for community based advocates to argue their point and not have to talk in code about ozone and PM_{10}. Just ask: 'How far can you see?' It's a repeatable, evidence based approach that is transferrable. Any place with an airstrip giving visibility readings to aviators would have the technical knowhow to gather this data."