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Public Health and Air Pollution in Asia (PAPA)

Protocol for Coordinated Time-Series Studies of Daily Mortality in Asian Cities

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Wong C-M, Vichit-Vadakan N, Kan H, Qian Z, and the PAPA Project Teams. Public Health and Air Pollution in Asia (PAPA): A multi-city for short-term effects of air pollution on mortality. Research Report. Health Effects Institute, Boston, MA. In press.

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PROTOCOL FOR COORDINATED TIME-SERIES STUDIES OF DAILY MORTALITY IN ASIAN CITIES

I. RATIONALE

The time-series studies of daily mortality in Asian countries are anticipated to produce a large international literature on air pollution and daily rates of mortality and hospital admissions, strengthening both that literature and the conclusions one could draw from the individual PAPA studies. Within Asia a wider breadth of such studies, especially if designed from the start to be comparable, would enhance region-specific combined analyses, providing more definitive estimates of local effects for decision makers.

Recent meta-analyses (Cohen AJ, Anderson HR, Ostro B, et al. 2004¹; PAPA Review) suggest that proportional increases in daily mortality per 10 $\mu\text{g}/\text{m}^3$ increase in PM₁₀ are similar among North America, Western Europe, and developing countries. However, there are relatively few meta-analysis studies in Asia. Most studies are not geographically representative, and have taken inconsistent approaches to the definition of health outcomes and data analyses that complicate comparisons with each other and with the broader literature. In addition, the worldwide data have not been appropriately analyzed to determine whether there are real differences in the magnitude of the effects of short-term exposure, and the reasons for these differences (e.g., differences in air pollution, population characteristics).

Efforts to bring the world's data together for such analyses are underway with funding from HEI and the EC in the APHENA project. These efforts would also be strengthened by the additional variability in air pollution, climate and population characteristics that Asian studies could contribute. The results of a coordinated set of time-series studies in Asia would also inform extrapolation to Asia of the results of US and European studies of the effects of long-term exposure on mortality from chronic cardiovascular and respiratory diseases.

¹ Cohen AJ, Anderson HR, Ostro B, Pandey KD, Krzyzanowski M, Kuenzli N, Gutschmidt K, Pope CA, Romieu I, Samet JM, Smith KR. 2004. Mortality impacts of urban air pollution. In: Comparative Quantification of Health Risks: Global and Regional Burden of Disease Due to Selected Major Risk Factors (Ezzati M, Lopez AD, Rodgers A, Murray CJL, eds), vol 2. World Health Organization, Geneva, Switzerland.

II. SPECIFIC OBJECTIVES

The specific objectives of a coordinated analysis of multi-city Asian data are to:

- Develop a protocol for the design and analysis of data from multiple Asian cities;
 - Develop a management framework to conduct the coordinated analysis;
 - Conduct coordinated analyses of common exposures and health endpoints according to the protocol, including meta-analyses to the extent possible;
 - Contribute to the international scientific discussion on the conduct and interpretation of time-series studies of the effects of short-term exposure;
 - Report the results of the coordinated analyses in an HEI final report and papers in the broader peer-reviewed literature.
 - Stimulate the development of routine systems for recording daily deaths and admissions for the purpose of time-series analysis.
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III. ELEMENTS OF A COORDINATED STUDY

The conduct of a coordinated set of time-series studies in Asia requires the development of a detailed protocol that describes the methodology. The methodology is described under the **Materials and Methods** section below, and includes a description of the participating centers, the design of the coordinated multi-city database, the design of the coordinated analyses, and the approach that will be taken by the participating investigators to the management of the coordinated analysis.

IV. MATERIALS AND METHODS

A. PARTICIPANTS

i. Participating Research Centers

- City selection includes rationale for selection, and description of city location (geographic, degree of urbanization, etc).
- Selection of cities has been governed by interests expressed by existing investigators through responses to RFIQs issued by HEI. The responses comprised cities with the current information and research capacity to conduct analyses in the cities to which they have access, and those who expressed interest but could not proceed without development of new databases or statistical capacity.

- Description of individual studies including population, available data, and personnel are as follows:

- **Bangkok**

Bangkok is proposing to examine the effects of PM₁₀ and several gaseous pollutants, i.e., ozone, nitrogen dioxide, and sulfur dioxide, on daily mortality for the years 1997 through 2003 and for all 50 districts of Bangkok. With the population of six to ten million people, Bangkok has an average of about 100 deaths per day. Both mortality and air quality data are computerized and readily available from the Registrar Office and the Pollution Control Department, respectively.

The team will test for gender- and age-stratified associations with mortality. It will also investigate disease-specific associations with mortality focusing on cardiovascular and pulmonary causes. In addition, during part of the period of the proposed study, Thailand experienced a serious recession. As a result, it will be able to assess whether an air pollution-mortality association existed during this period and also whether the likely reductions in traffic during the recession were associated with lower mortality rates. The proposed research team of Thai and U.S. researchers has had considerable experience conducting time-series studies and in working in Thailand. The team is composed of Dr. Nuntavarn Vichit-Vadakan (PI), Dr. Bart Ostro, Dr. Nitaya Vajanapoom, and Dr. Wichai Akeplakorn.

- **Hong Kong**

In Hong Kong, time-series studies will be performed for short-term effects of air pollution on mortality and hospital admissions. The confounding and modifying effects of influenza epidemics will also be assessed. The studies will include the whole Hong Kong population of 6.8 million with an age distribution: 23% < 20; 62% 20-59 and 15% 60+ years. The period of the study spans from the year 1996 to 2002. During this period, the health outcome data, air pollution data, and other covariates are available in electronic form. In addition, there are By-Census (5 yearly) and Census data (10 yearly) within the period, thus providing socioeconomic and demographic information about the population for better interpretation of the results of the study. The investigators from the Hong Kong team include: Dr. CM Wong (PI), Prof. JSM Peiris, Prof. AJ Hedley, Dr. TQ Thach, Dr. GN Thomas and Prof. TH Lam of the University of Hong Kong as well as Prof. TW Wong of the Chinese University of Hong Kong.

- **Shanghai**

In Shanghai, a time-series study will be conducted to evaluate the association between mortality outcomes and major air pollutants, using four years of daily data (2001-2004). The target population will include all residents living in the urban area of Shanghai covering nine districts and having a population of more than six million. Daily mortality data will be extracted from the database of Shanghai Municipal Center of Disease Control and Prevention, and will be classified into deaths due to cardiovascular diseases, respiratory diseases according to the International Classification of Diseases, Revision 10. Daily air pollution data during the study period, including PM₁₀, SO₂, NO₂ and O₃, will be monitored at six fixed-site stations by the Shanghai Environmental Monitoring Center. The investigators from Shanghai team include: 1. Drs Haidong Kan (PI), Bingheng Chen, and Naiqing Zhao from Fudan University School of Public Health; 2. Drs Guixiang Song and Changyi Guo from the Shanghai Municipal Center of Disease Control and Prevention; 3. Drs Guohai Chen and Zuci Shan from the Shanghai Environmental Monitoring Center.

- **Wuhan**

This study will be conducted to determine whether daily variations in ambient PM₁₀ concentrations in Wuhan during the four years from July 1, 2000 to June 30, 2004 are associated with daily variations in non-accidental mortality and with daily cause-specific mortality. Five fixed-site air-monitoring stations of the Wuhan Air Quality Automatic Monitoring System, operated by the Wuhan Center of Environmental Monitoring and certified by the U.S. Environmental Protection Agency, will provide daily mean concentrations of PM₁₀, SO₂, and NO₂. (O₃ will be provided by only two stations.) Daily mortality data from approximately 4.3 million permanent residents in the nine urban core districts of Wuhan will be available during the study period. The investigators include Dr. Zhengmin Qian (PI), Pennsylvania State University (PSU); Prof. Qingci He (Co-PI), Wuhan Academy of Environmental Science (WAES); Dr. Hung-Mo Lin, PSU; Dr. Duanping Liao, PSU; Dr. Lingli Kong, WAES; Dr. Dunjing Zhou, Wuhan Centres for Disease Prevention and Control; and Dr. Beiwei Wang, Wuhan Center of Environmental Monitoring.

ii. HEI:

- The International Scientific Oversight Committee (ISOC) acting on behalf of HEI, will oversee the conduct of the coordinated analyses via a combination of regular progress reports, periodic site visits, conference calls, and participation in HEI Annual Conferences. The ISOC and HEI staff will be available to provide support and technical advice to the investigators as needed upon request. Once the analyses have been completed a final report will be published by HEI after review by the HEI Review Committee. The Review Committee will also prepare a Commentary on the report that will be published with it.

B. DESIGN OF DATA

i. Health outcomes

The focus of the coordinated analysis will be on: 1) estimating daily mortality relative rates for all natural causes, and cardiovascular and respiratory diseases; and 2) estimating daily mortality relative rates for the causes of death categories by age and sex, as specified below. The quality of the health data will be assessed and taken into account in both analysis and interpretation of results, to the extent possible.

Causes of death	Age group	Sex	ICD-9	ICD-10	Notes
All natural causes	all ages, 0-4, 5-44, 45-64, 65+, 45+ (optional)	both sexes; stratified by male and female	001-799	A00-R99	All natural causes include all non-traumatic, non-suicidal and non-poisoning causes.
Cardio-pulmonary	all ages	both sexes	390-459, 460-519	I00-I99, J00-J98	This includes both cardiovascular and respiratory diseases rubrics.
Cardiovascular	all ages	both sexes	390-459	I00-I99	This is the whole circulatory disease rubric. However, cardiovascular is a better term and one that is commonly used. This would include <i>cor pulmonale</i> including acute and chronic pulmonary heart diseases with ICD-9 = 415-416; ICD-10 = I26-I27.
Stroke	all ages	both sexes	430-438	I60-I69	(Optional) This includes the whole cerebrovascular diseases rubric. However, calling it stroke may reduce confusion with cardiovascular. It will include a few uncommon cerebrovascular conditions not manifested as stroke.
Cardiac or heart diseases	all ages	both sexes	390-398, 410-429	I00-I09, I20-I52	(Optional)
Respiratory	all ages	both sexes	460-519	J00-J98	This is the whole respiratory disease rubric.
Lower respiratory infections	all ages	both sexes	466, 480-487	J10-J22	(Optional) This includes influenza, which at this level is usually pneumonic.
Chronic obstructive pulmonary diseases (COPD)	all ages	both sexes	490-496	J40-J47	(Optional) This is not really COPD in younger persons as it would also contain asthma (ICD-9 = 493; ICD-10 = J45-J46). This is acceptable because asthma is not a common cause of death, and because in the elderly there is little point in distinguishing between asthma and COPD.
Tuberculosis	all ages	both sexes	010-018	A15-A19	(Optional)
Control diseases: digestive and genitourinary	all ages	both sexes	520-629	K00-K93, N00-N99	(Optional) All these categories had been used as controls in an intervention study for Hong Kong with results published in Hedley et al. (Lancet 2002; 360: 1646-52).
all neoplasm excluding lung cancer	all ages	both sexes	140-161, 163-239	C00-C32, C37-D48	

We chose the above relatively wide range of categories of cause of death for this coordinated time-series study for we expect that this approach may reduce misclassification of underlying cause of death among the four study cities.

It is recognized that ICD-9 and ICD-10 coded mortality datasets will be used to compile mortality time-series, with different degree of combination by study cities. The proposed study periods and dates of change from ICD-9 to ICD-10 in the four cities are as follows:

	Bangkok	Hong Kong	Shanghai	PSU-Wuhan
Study period	June 1 st , 1997- May 31 st , 2003	January 1 st , 1996-December 31 st , 2002	January 1 st , 2001- December 31 st , 2004	July 1 st , 2000- June 30 th , 2004
Date of change to ICD-10	1994	January 1 st , 2001	January 1 st , 2002	January 1 st , 2003

To facilitate conversion and checking between ICD-9 and ICD-10 codes, a supplementary information sheet for the two coding systems is provided in Annex A. Special attention from each city will be paid to recognize and identify a potential shift in mortality data around the change of ICD coding period. Utilization of ICD-9 or ICD-10 is often the decision of the respective national center for disease control (CDC) or equivalent health surveillance agency. The investigators in these four studies have no influence on the decision. In other words, they were bounded by whatever is available from their respective CDCs. Since the time series data will be compiled according to the four very wide ranges of cause-specific mortality, potential misclassification of such widely-defined causes of death is less serious a problem than analyzing smaller categories of causes of death.

ii. Assessment of quality of health outcome data

Using mortality datasets that contain individual-level information, each city will conduct descriptive analyses to obtain the frequency distributions and/or univariate distributions for all categorical variables (e.g., sex) as well as continuous variables (e.g., age). Investigators in each city will carefully check these distributions for the miscoded, missing, and out of range data. Errors, questions, and/or concerns regarding specific data points will be discussed, validated, answered, and corrected in each city.

We notice that documentation of cross validation for causes of death (causes of death from death certificates vs. true causes of death from hospital chart review) may be available locally among the four study cities. Each city should make efforts to assemble the relevant literature and government publications documenting the validity and accuracy of classified causes of death.

In addition to examining univariate distributions for all categorical and continuous variables in each city, it will be important to examine the distributions of the causes of death as well.

iii. City-specific considerations (additional efforts each city needs to take and the difficulties each city would encounter in order to implement this protocol)

- **Bangkok**

The Bangkok team wishes to capitalize on the natural economic occurrence that occurred in 1997 by examining whether the reductions in local traffic levels during the recession impacted mortality rates and resultant concentration-response functions.

- **Hong Kong**

The Hong Kong team will not study the optional outcome, tuberculosis, as the numbers are small; but it will study mortality due to control diseases.

- **Shanghai**

(No specific considerations)

- **Wuhan**

The PSU-Wuhan team will test interactions between PM₁₀ exposure and low or high temperatures on daily mortality. It may also perform district stratification analyses, depending on the results of correlations among the pollutants' measurements from the five monitoring stations, as well as the results of relevant sensitivity analyses.

iv. Air Pollution

The major analytic objective is to estimate the population daily average air pollution exposure in each city. Mortality relative rate ratios will be estimated for selected particulate and gaseous components of the air pollution mixture measured daily. The same averaging times will be applied to each pollutant. The quality of the air pollution data will be evaluated for each city and taken into account in both analysis and interpretation of results via review and analysis of the data, as well as documentation of past and current QC procedures, to the extent possible.

v. Monitoring period

- **Bangkok:** June 1st, 1997 – May 31st, 2003
- **Hong Kong:** January 1st, 1996 – December 31st, 2002
- **Shanghai:** January 1st, 2001 – December 31st, 2004
- **Wuhan:** July 1st, 2000 – June 30th, 2004

vi. Air quality indicators

After discussion at the PAPA Investigators' Workshop in Bangkok, the following air quality indicators are proposed:

Pollutant	Averaging time
Sulphur dioxide (SO ₂)	24-hr average
Nitrogen dioxide (NO ₂)	24-hr average
Particulate matter (aerodynamic diameter of 10 micrometres or smaller) (PM ₁₀)	24-hr average (PM _{2.5} as optional indicator where available)
Ozone (O ₃)	8-hr average (from 10:00 – 18:00)
Carbon monoxide (CO)	as optional indicator where available

vii. Site selection criteria

With respect to the site selection criteria of PAPA, it is recommended to use the criteria established below:

- Basically, the sites to be selected should be representative of the exposure of population and take into account the time scale of their effects on health. The sites shall reflect the urban background level of air pollution, thereby excluding those in the direct vicinity of traffic or of industrial sources. The location shall also avoid buildings housing large emitters such as coal-, waste-, or oil-burning boilers, furnaces, and incinerators.
- The sites should not be influenced by local sources (highways, industries, open burning).
- The sites should be large enough to ensure the availability of space for monitoring, and should be located in flat space and elevated between one and 14 m above ground level. The elevated height shall be determined according to the relevant rules & regulations of each country. (Note: In the US, the monitoring site shall be elevated between 3 and 15 m above ground level according to "40 CFR - CHAPTER I - PART 58 Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring". However, European urban background sites are approximately 3m closer to the ground in general.)
- Curbside (or roadside) stations should not be included.
- The sites should be located 5 m upwind from building exhausts and at least 2 m from walls.
- A single monitor may be insufficient to assess the population exposure level in the study region. Therefore, it is recommended that a number of monitoring stations be used to reflect the exposure of the population at risk. These stations should comply with the site selection criteria described above. The correlations among the measurements from various stations will be examined.

viii. Measurement methods

The measurement methods used for air quality assessment in the four cities should comply with the relevant rules & regulations of each country. Methods of measurement for gaseous pollutants, for

example, have been fairly standardized, in that UV fluorescence for SO₂ and chemiluminescence for NO₂ are usually used. For PM₁₀, the measurement will be performed with TEOM or Beta absorption instruments in the four cities.

ix. QA/QC

Two primary documents, QAPP (Quality Assurance Program Plan) and SOP (Standard Operating Procedure), are needed for each city. Each city will obtain these documents and review them to answer data quality questions to be provided.

All four cities have a quality control programme in order to conform to each country's requirements. In Wuhan and Shanghai, air quality data should generally be collected at the monitoring stations under National Quality Control.

x. Completeness criteria

For the calculation of 24-hour average concentration of NO₂, SO₂ and PM₁₀, it is required to have at least 75% of the one-hour values on that particular day. For the 8-hour average of O₃, at least six hourly values from 10:00 to 18:00 have to be available.

If a station has more than 25% of the values missing for the whole period of analysis, the entire station should be excluded from the study.

xi. Missing data

According to the completeness criteria, there may be missing values in the air pollutant series for a small (**NB the proportion may not be "small"**) proportion of the study period. In the primary analysis in stage 1, only the actual collected data (based on each day having at least 75% of the hours collected and at least 75% of daily data being available for the whole study period for each station) will be used, and missing data will not be filled in. In the sensitivity analysis, the individual study centers will use a method of centering to adjust for the effect of difference in weighting between stations, as described below.

Box No.1: Method of Centering:

Non-missing daily means are first centered for each station i [i.e., individual daily concentrations (X_{ij}) are subtracted by an annual station mean (X_i) for each day j]. The centered data from all centers are then combined and added into the annual mean of all stations (X) to form $X'_{ij} = (X_{ij} - X_i + X)$. The daily (mean) concentrations of individual pollutant are computed for analysis by taking the mean of X'_{ij} over all stations (Wong *et al.* 2001).

Wong, C.M., Ma, S., Hedley, A.J., Lam, T.H. 2001. Effect of air pollution on daily mortality in Hong Kong. *Environmental Health Perspectives* 109: 335-340.

xii. PAPA/ISOC request for basic monitoring information

In order to facilitate harmonization and comparison of the information relevant to the exposure assessments in the 4 cities of PAPA, a questionnaire was prepared and attached below as Annex B in this protocol.

xiii. Other co-variates

The analytic objective is to identify and specify for purposes of analysis a common set of time-varying potential confounders to be controlled. These comprise meteorological, social, and medical factors.

- **Meteorological covariates**
Temperature: daily average
Humidity: daily average RH/Dew point
- **Calendar variables**
Special events e.g., strikes
Dummy variables for:
 - (1) Official public holidays
 - (2) Days of the week
- **Use of data on Influenza/other epidemics (optional)**
The Hong Kong team will assess the effect of influenza in its city specific study. For all cities, influenza epidemics could be defined as weekly number of respiratory mortality above the 90th percentile in each year of the city, and be taken into account as one of the model improvement methods (Box No.2) in sensitivity analysis.

C. DESIGN OF ANALYSIS

A two-stage analysis of multi-city time-series data collected as part of the PAPA project is envisaged. The design of the second stage analysis will be constrained by the small number of studies that will be conducted (anywhere from 4 to 8). Nevertheless, summary estimates should be estimable at a minimum.

i. Single-city (1st stage) analysis

For the core model, all of the four study centers will use the same regression model. Specifically, the procedure will involve the following:

1. Generalized Additive Model (GAM) with penalized and natural spline smoothers in R.
2. Poisson function with mortality due to cardiovascular, respiratory and all natural causes as dependent variables.
3. Smoother for time using 4-6 dfs per year of data.
4. Smoothers for the mean daily temperature and mean daily humidity using 3 dfs (whole period of study) each at a zero day lag. (Individual study centers can employ sensitivity analysis to examine other specifications for weather terms.)

5. Day of week terms (i.e, dichotomous variables for each day of the week from Monday through Saturday).
6. Dichotomous variables relevant to individual city, if available: public holidays (Hong Kong) and extreme weather conditions (Wuhan).
7. Exposure at single-day lags of 0 to 4 days, a two-day average of lags 0 and 1 and a five-day average of lags 0 to 4 (inclusive).

The results will be reported to the Technical Support Group or to a website along with statistics indicating the degree of overdispersion and a graph of the autocorrelation function. The AIC will not be used as a model selection criterion for this core model. If there is overdispersion in the variance, this will then be adjusted in a second model. If first- or second-order autocorrelation of the residuals with $|\rho| > 0.1$ is present (independent of the associated p-values) based on the partial autocorrelation function (PACF), the study center will then alter (probably increase) the degrees of freedom in the smoother of time until $|\rho| \leq 0.1$.

After this base case core model is developed, other specifications, using selected lags, will be used to examine the common mortality outcomes.

Ultimately, each study center will conduct sensitivity analyses on their own data sets (as detailed). For example, some centers will want to control for flu epidemics, examine different disease aggregations, weather variables, etc. However, more harmonization of approaches to sensitivity analyses among centers will be suggested. Some analyses can and should be done by all.

For implementation of the core model development and data analysis, the following guidelines were established as shown in Box No.2 on the next page.

Box No. 2: Data Analysis Guidelines (Notes of meeting on April 18, 2005, 6:00-7:30 pm in Baltimore)

1. Criteria for adequacy in core models: When the absolute magnitude of PACF plot is less than 0.1 for the first two lag days as specified in items no.1-7 of Section C (i) above, the core model is regarded as adequate. If these criteria are not met, it is advisable to take some steps to meet these criteria, as described in item No. 2 below.
2. Improvement of model adequacy by trying the following three methods in order and selecting 1-3 methods as appropriate.
 - a. Localized smoothing:
 - Identify and define dummy variables (q) for periods with extra and/or systematic variation in the residual plot
 - Define interaction variables $I = q \times \text{time}$
 - Add smoothing function of I with certain degrees of freedom
 - b. Inclusion of epidemic variables as defined in item No.6 (b) below
 - c. Introduction of auto-regression terms:

Other than localized smoothing and inclusion of influenza epidemic indicator variables, the model can be improved by introduction of auto-regression terms for lag up to 7 days. This method is particularly useful when the PACFs are consistently positive or negative for the first several lag days. This method was added after discussion with members subsequent to the Baltimore meeting.
3. Missing data handling and centering: Clarify that missing data will not be filled in. But to eliminate discrepancies between stations daily data in each center will be centered (Box No.1) on each individual overall station mean before computation of city specific daily data. However, since Shanghai does not have pollutant data for individual stations and cannot perform centering for the data, we may use simple averaging for the main analysis and use centering for the sensitivity analysis.
4. Multiple pollutant modeling: Decide to use same lag for pair of co-pollutants (PM₁₀ with SO₂ and PM₁₀ with NO₂) in the best model developed for all natural causes.
5. Dose-response curve: Smoothing function of each pollutant with 3-4 dfs using natural spline will be fitted for model of all natural causes of death. Y-axis should be residual after fitting of non-pollutant variables.
6. Sensitivity analysis: This should include changes in effect estimates (a) using definition of daily pollutant data with centering; (b) adjustment for epidemics defined by weekly respiratory mortality >90th percentile each year; (c) varying the dfs of time smoother from 3 to 15.
7. Cross validation of results: Each team will validate the estimates derived from model of one other team.

ii. Multi-city (2nd-stage) analysis

In the 1st stage of the project, some common data analysis methods and guidelines have been established, in which a standardized analytical framework is applied to time-series data across 4 cities. In this way, this should have avoided some sources of biases which might have otherwise occurred and enable us to carry out a meta-analysis.

The main aim of meta-analysis is to enable the results of the studies to be visually inspected using Forest plots so that a judgment could be made about the overall direction of the evidence. We test for heterogeneity (variation between cities in individual studies) and calculate combined estimate for effect on mortality.

1. Quality assurance:

Before performing meta-analysis for combined estimates of effects across cities, quality of the data collection methods and data quality have to be recorded and assessed first. The size of the data and other factors, which would affect the variation in the estimates, should also be recorded and assessed first. The factors can then be taken into account when calculating a combined estimate for an effect.

First a standardized data format is designed (Annex C) so that the coordinator of the project could arrange validation of the study results. Data sets documented in the standardized format are sent to other groups for re-running the models or re-analysis of the data.

Each team should also record the main effect estimates in another standardized forms (Annex D and E) and send them to the coordinator for cross-checking with results derived from re-analysis.

2. Further analysis:

Single lag effects: In order to make results comparable to estimates from Poisson regression, log-relative risks (regression estimates) will be converted into a standard metric: log-relative risk associated with a $10 \mu\text{g}/\text{m}^3$ increase in the pollutant.

3. Co-pollutant effects:

In the first stage, we performed two pollutant models in which PM_{10} or NO_2 were analyzed with other pollutants in the model as part of sensitivity analysis. The aim was to see how robust each of these pollutants was to the inclusion of other pollutants. The concept is that those pollutants that are most robust in two pollutant or multi-pollutant models have a more convincing case for being closer to the causal pathway. Caution must be exercised in the interpretation of such analyses, however, because the estimates obtained tend to be less precise. This means that confidence intervals may be widened even when the point estimate is relatively unchanged.

It is proposed to obtain combined estimates for the following

- PM₁₀ single estimates
- PM₁₀ controlling for NO₂
- PM₁₀ controlling for O₃
- PM₁₀ controlling for SO₂

4. Meta-analysis and summary estimates:

Regression estimates and standard errors for studies will be used to obtain combined effect estimates based on fixed- and random-effects models (DerSimonian and Laird, 1986).

5. Cross-validation of results and sensitivity analysis:

The guidelines for performing the sensitivity analysis were developed during the regional meeting held in Hong Kong on November 30th and December 1st of 2005. The notes of the meeting are outlined in Box 3 below.

Box No. 3: Notes from regional meeting held in Hong Kong on November 30, 2005 and December 1, 2005.

Cross-validation, sensitivity analysis and information for meta-analysis:

1. Cross-validate results by each other within Hong Kong-Wuhan, and Bangkok-Shanghai for
 - a. All causes, 65+ with NO₂ and all lags
 - b. All natural causes, all ages with PM₁₀ and all lags
2. Present dose-response curve of all pollutants for all causes with 4 df over time
3. Sensitivity analysis: repeat the analysis for all-cause and cardiovascular mortality (all lags) (with city-specific "best" core model) with
 - a. PM₁₀ & O₃: Top 5% percentile removed;
 - b. PM₁₀: Measurements restricted to ≤ 180 µg/m³ (2 separate analyses);
 - c. PM₁₀: Monitors with the two highest NO/NO_x (NO = NO_x-NO₂) dropped, where NO/NO_x is a good marker for auto traffic (if data are not available, drop the two stations which are highly influenced by traffic or largely from industrial sources); and
 - d. PM₁₀: Only the non-rainy period adopted (the non-rainy period varies according to cities)
4. Information required for meta-analysis:
 - a. In order to perform the meta-analysis, the HK team needs the attached information (spreadsheets of Annex C, D, E and F) from all the cities.
 - b. Ideally, the information should be based on city-level. If a city does not have the required information by city-level, district- or provincial-level would be acceptable.
 - c. It is not necessary to have up-to-date information. If not all the above-mentioned information could be obtained, the cities should provide the information available.
 - d. Unavailable information should be marked "NA" in the spreadsheets.

6. Task and Budget Justification for coordinated studies:

a. Basic analysis - to be performed by each individual team (Budget \$20,000x4)

- Model for health outcomes specified in common protocol
- Display and tabulate diagnostic results
- Tabulate effect estimates
- Submit the data sets and the effect estimates to the coordinator
- Validate (repeat) the models for one other team
- Participate in data analysis and interpretation of results
- Contribute to report writing

b. Meta analysis - to be undertaken by Hong Kong team (\$10,000)

- Receive the original and validated results from all other teams
- Assess the validity of the models
- Perform pooled or meta analysis for effect estimates of 4 cities
- Plot and tabulate results
- Write the methods and results sections for the meta-analysis

c. Report writing - to be undertaken by Hong Kong team (\$5,000)

- Write the introduction section with a literature review
- Write the methods and results sections with input from b above
- Address the issues of the coordinated studies
- Finalize the report for the coordinated studies

d. Communication - to be undertaken by Bangkok (\$5,000)

- Set time line
- Facilitate tasks among teams and communication with HEI and APHENA
- Organize and prepare materials for meetings and workshops
- Communicate the main tasks of the coordinated studies
- Consult (Dr Bart Ostro) for statistical methods in Tasks b and c
- Assist in producing the final report

D. PROJECT COORDINATION AND INTERACTION AMONG INVESTIGATORS

There are two main parallel courses in the implementation of the mortality time-series study for the 4 cities, that is, the individual city study and the coordinated study among the 4 cities.

A system of coordination and communication is needed to implement the study effectively and efficiently. In terms of interaction among the investigators, web-based communication (i.e. project message board with link to e-mail notification, and webpage for updating study activities) is developed. Summary of activities and problems encountered with remedial plan of each of the project components listed below may be posted on the message board. HEI is responsible for development and maintenance of the message board. For each of the components, one member from each team acts as the site facilitator who passes on relevant messages to other team members, and regularly posts updates from the team on the message board. One member from each team will be designated the first point of contact. The critical issues for the coordinated study focus on (1) the data management, (2) data analysis, report writing and (3) dissemination of results. A steering committee is to be coordinated by the Hong Kong team to manage the coordinated study. The main functions include the following:

1. Guide the investigators during the study period when needed
2. Monitor the adherence of protocol, specifically, the aforementioned critical issues
3. Develop guideline for dissemination of results
4. Resolve any disagreement

The steering committee is composed of two to three representatives including the P.I. from each of the four teams. The main communication mechanism is web-based, i.e., e-mail mainly and chat room. The steering committee, once formed, schedules a monthly forum (to be determined) to discuss specific issues. The regional meeting as proposed by HEI may also be used to resolve any challenges and update activities.

In addition, the coordination tasks may be divided into 2 main categories, i.e., coordination on technical issues and coordination on administrative issues. It is proposed that CM Wong, Bart Ostro, Hung-Mo Lin and Dr. Naiqing Zhao take the role of coordinators in the Technical Support Group for technical matters, and Aaron Cohen and Wei Huang assume the role of administrative coordinators.

-----End of Protocol-----

**Annex A: Supplementary information updated in May 2004
(not part of the protocol) – Conversion of ICD-9 to ICD-10**

ICD-9		ICD-10	
Underlying cause of death	Codes	Underlying cause of death	Codes
Natural/nonaccidental	1-799	Natural/nonaccidental	A00-R99
Respiratory (RD)	460-519	Respiratory (RD)	J00-J98
Acute nasopharyngitis	460	Acute upper respiratory infections	J00-J06
Acute sinusitis	461	Acute nasopharyngitis (common cold)	J00
Acute pharyngitis	462	Acute sinusitis	J01
Acute tonsillitis	463	Acute pharyngitis	J02
Acute laryngitis and tracheitis	464	Acute tonsillitis	J03
Acute upper respiratory infections of multiple or unspecified sites	465	Acute laryngitis and tracheitis	J04
Acute bronchitis and bronchiolitis	466	Acute obstructive laryngitis and epiglottitis	J05
Deviated nasal septum	470	Acute upper respiratory infections of multiple and unspecified sites	J06
Nasal polyps	471	Influenza and pneumonia	J10-J18
Chronic pharyngitis and nasopharyngitis	472	Influenza due to identified influenza virus	J10
Chronic sinusitis	473	Influenza, virus not identified	J11
Chronic disease of tonsils and adenoids	474	Viral pneumonia, not elsewhere classified	J12
Peritonsillar abscess	475	Pneumonia due to Streptococcus pneumoniae	J13
Chronic laryngitis and laryngotracheitis	476	Pneumonia due to Haemophilus influenzae	J14
Allergic rhinitis	477	Bacterial pneumonia, not elsewhere classified	J15
Other diseases of upper respiratory tract	478	Pneumonia due to other infectious organisms, not elsewhere classified	J16
Viral pneumonia	480	Pneumonia in diseases classified elsewhere	J17
Pneumococcal pneumonia	481	Pneumonia, organism unspecified	J18
Other bacterial pneumonia	482	Other acute lower respiratory infections	J20-J22
Pneumonia due to other specified organism	483	Acute bronchitis	J20
Pneumonia in infectious diseases classified elsewhere	484	Acute bronchiolitis	J21
Bronchopneumonia, organism unspecified	485	Unspecified acute lower respiratory infection	J22
Pneumonia, organism unspecified	486	Other diseases of upper respiratory tract	J30-J39
Influenza	487	Vasomotor and allergic rhinitis	J30
Bronchitis, not specified as acute or chronic	490	Chronic rhinitis, nasopharyngitis and pharyngitis	J31
Chronic bronchitis	491	Chronic sinusitis	J32
Emphysema	492	Nasal polyp	J33
Asthma	493	Other disorders of nose and nasal sinuses	J34
Bronchiectasis	494	Chronic diseases of tonsils and adenoids	J35
Extrinsic allergic alveolitis	495	Peritonsillar abscess	J36
Chronic airway obstruction, not elsewhere classified	496	Chronic laryngitis and laryngotracheitis	J37
Coal workers' pneumoconiosis	500	Diseases of vocal cords and larynx, not elsewhere classified	J38
Asbestosis	501	Other diseases of upper respiratory tract	J39
Pneumoconiosis due to other silica or silicates	502	Chronic lower respiratory diseases	J40-J47
Pneumoconiosis due to other inorganic dust	503	Bronchitis, not specified as acute or chronic	J40
Pneumonopathy due to inhalation of other dust	504	Simple and mucopurulent chronic bronchitis	J41
Pneumoconiosis, unspecified	505	Unspecified chronic bronchitis	J42
Respiratory conditions due to chemical fumes and vapors	506	Emphysema	J43
Pneumonitis due to solids and liquids	507		
Respiratory conditions due to other and unspecified external agents	508		
Empyema	510		
Pleurisy	511		
Pneumothorax	512		
Abscess of lung and mediastinum	513		

Pulmonary congestion and hypostasis	514	Other chronic obstructive pulmonary disease	J44
Postinflammatory pulmonary fibrosis	515	Asthma	J45
Other alveolar and parietoalveolar pneumonopathy	516	Status asthmaticus	J46
Lung involvement in conditions classified elsewhere	517	Bronchiectasis	J47
Other diseases of lung	518	Lung diseases due to external agents	J60-J70
Other diseases of respiratory system	519	Coalworker's pneumoconiosis	J60
		Pneumoconiosis due to asbestos and other mineral fibres	J61
		Pneumoconiosis due to dust containing silica	J62
		Pneumoconiosis due to other inorganic dusts	J63
		Unspecified pneumoconiosis	J64
		Pneumoconiosis associated with tuberculosis	J65
		Airway disease due to specific organic dust	J66
		Hypersensitivity pneumonitis due to organic dust	J67
		Respiratory conditions due to inhalation of chemicals, gases, fumes and vapours	J68
		Pneumonitis due to solids and liquids	J69
		Respiratory conditions due to other external agents	J70
		Other respiratory diseases principally affecting the interstitium	J80-J84
		Adult respiratory distress syndrome	J80
		Pulmonary oedema	J81
		Pulmonary eosinophilia, not elsewhere classified	J82
		Other interstitial pulmonary diseases	J84
		Suppurative and necrotic conditions of lower respiratory tract	J85-J86
		Abscess of lung and mediastinum	J85
		Pyothorax	J86
		Other diseases of pleura	J90-J94
		Pleural effusion, not elsewhere classified	J90
		Pleural effusion in conditions classified elsewhere	J91
		Pleural plaque	J92
		Pneumothorax	J93
		Other pleural conditions	J94
		Other diseases of the respiratory system	J95-J99
		Postprocedural respiratory disorders, not elsewhere classified	J95
		Respiratory failure, not elsewhere classified	J96
		Other respiratory disorders	J98
		Respiratory disorders in diseases classified elsewhere	J99
Cardiovascular (CVD)	390-459	Cardiovascular (CVD)	100-199
Rheumatic fever without mention of heart involvement	390	Acute rheumatic fever	100-102
Rheumatic fever with heart involvement	391	Rheumatic fever without mention of heart involvement	100
Rheumatic chorea	392	Rheumatic fever with of heart involvement	101
Chronic rheumatic pericarditis	393	Rheumatic chorea	102
Disease of mitral valve	394		

Disease of aortic valve	395	Chronic rheumatic heart diseases	I05-I09
Disease of mitral and aortic valves	396	Rheumatic mitral valve diseases	I05
Disease of other endocardial structures	397	Rheumatic aortic valve diseases	I06
Other rheumatic heart disease	398	Rheumatic tricuspid valve diseases	I07
Essential hypertension	401	Multiple valve diseases	I08
Hypertension heart disease	402	Other rheumatic heart diseases	I09
Hypertension renal disease	403	Hypertensive diseases	I10-I15
Hypertension heart and renal disease	404	Essential (primary) hypertension	I10
Second hypertension	405	Hypertensive heart disease	I11
Acute myocardial infarction	410	Hypertensive renal disease	I12
Other acute and subacute forms of ischemic	411	Hypertensive heart and renal disease	I13
Old myocardial infarction	412	Secondary hypertension	I15
Angina pectoris	413	Ischaemic heart diseases	I20-I25
Other forms of chronic ischemic heart disease	414	Angina pectoris	I20
Acute pulmonary heart disease	415	Acute myocardial infarction	I21
Chronic pulmonary heart disease	416	Subsequent myocardial infarction	I22
Other diseases of pulmonary circulation	417	Certain current complications following	I23
Acute pericarditis	420	acute myocardial infarction	
Acute and subacute endocarditis	421	Other acute ischaemic heart diseases	I24
Acute myocarditis	422	Chronic ischaemic heart disease	I25
Other diseases of pericardium	423	Pulmonary heart disease and diseases of	I26-I28
Other diseases of endocardium	424	pulmonary circulation	
Cardiomyopathy	425	Pulmonary embolism	I26
Conduction disorders	426	Other pulmonary heart diseases	I27
Cardiac dysrhythmias	427	Other ischaemic heart vessels	I28
Heart failure	428	Other forms of heart disease	I30-I52
Ill-defined descriptions and complications of heart	429	Acute pericarditis	I30
diseases		Other diseases of pericardium	I31
Atherosclerosis	440	Pericarditis in diseases classified	I32
Aortic aneurysm and dissection	441	elsewhere	
Other aneurysm	442	Acute and subacute endocarditis	I33
Other peripheral vascular disease	443	Nonrheumatic mitral valve disorders	I34
Arterial embolism and thrombosis	444	Nonrheumatic aortic valve disorders	I35
Polyarteritis nodosa and allied conditions	446	Nonrheumatic tricuspid valve disorders	I36
Other disorders of arteries and arterioles	447	Pulmonary valve disorders	I37
Disease of capillaries	448	Endocarditis, valve unspecified	I38
Phlebitis and thrombophlebitis	451	Endocarditis and heart valve disorders in	I39
Portal vein thrombosis	452	diseases classified elsewhere	
Other venous embolism and thrombosis	453	Acute myocarditis	I40
Varicose veins of lower extremities	454	Myocarditis in diseases classified	I41
Hemorrhoids	455	elsewhere	
Varicose veins of other sites	456	Cardiomyopathy	I42
Noninfectious disorders of lymphatic channels	457	Cardiomyopathy in diseases classified	I43
Hypotension	458	elsewhere	
Other disorders of circulatory system	459	Atrioventricular and left bundle-branch	I44
		block	
		Other conduction disorders	I45
		Cardiac arrest	I46
		Paroxysmal tachycardia	I47
		Atrial fibrillation and flutter	I48
		Other cardiac arrhythmias	I49
		Heart failure	I50
		Complications and ill-defined descriptions	I51
		of heart disease	
		Other heart disorders in diseases	I52
		classified elsewhere	
		Diseases of arteries, arterioles and	I70-I79
		capillaries	
		Atherosclerosis	I70
		Aortic aneurysm and dissection	I71

		Other aneurysm	172
		Other peripheral vascular diseases	173
		Arterial embolism and thrombosis	174
		Other disorders of arteries and arterioles	177
		Diseases of capillaries	178
		Disorders of arteries, arterioles and capillaries in diseases classified elsewhere	179
		Diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified	180-189
		Phlebitis and thrombophlebitis	180
		Portal vein thrombosis	181
		Other venous embolism and thrombosis	182
		Varicose veins of lower extremities	183
		Haemorrhoids	184
		Oesophageal varices	185
		Varicose veins of other sites	186
		Other disorders of veins	187
		Nonspecific lymphadenitis	188
		Other noninfective disorders of lymphatic vessels and lymph nodes	189
		Other and unspecified disorders of the circulatory system	195-199
		Hypotension	195
		Postprocedural disorders of circulatory system, not elsewhere classified	197
		Other disorders of circulatory system in diseases classified elsewhere	198
		Other and unspecified disorders of circulatory system	199
Stroke	430-438	Stroke	160-169
Subarachnoid hemorrhage	430	Subarachnoid haemorrhage	160
Intracerebral hemorrhage	431	Intracerebral haemorrhage	161
Other and unspecified intracranial hemorrhage	432	Other nontraumatic intracranial haemorrhage	162
Occlusion and stenosis of precerebral arteries	433	Cerebral infarction	163
Occlusion of cerebral arteries	434	Stroke, not specified as haemorrhage or infarction	164
Transient cerebral ischemia	435	Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction	165
Acute, but ill-defined, cerebrovascular disease	436	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	166
Other and ill-defined cerebrovascular disease	437	Other cerebrovascular diseases	167
Late effects of cerebrovascular disease	438	Cerebrovascular disorders in diseases classified elsewhere	168
		Sequelae of cerebrovascular disease	169
Others	1-389, 520-799	Others	A00-H95, K00-R99

Annex B: PAPA/ISOC request for basic monitoring information

The following questionnaire was prepared as a general guideline by Dr. Kenneth Demerjian, following our discussion in Bangkok. It is designed to compile information regarding the monitors and their measurements being used by PAPA investigators.

Monitor site characterization

- 1) Measurement characterization
- 2) Monitoring network characterization

This information, which should be routinely available in the documentation of monitoring networks (and described in the current draft protocol), will be helpful in characterizing and harmonizing data quality across the study regions and in ensuring the quality of the data that you rely upon in your city. In order to not place too heavy a burden on you in starting your study, we have indicated with “*” the items in information category 1) and 2) that are of highest priority and with which you should begin. The other items are optional to be answered at the current stage, but you should try to obtain such information as much as possible during the study period. Information on monitoring network characterization is also very important for data analysis; you should try to provide this information as soon as you have obtained full access to air monitoring data in your region.

Monitor site characterization (important to determine how well sites represent population exposure)

*Site ID:

*Site Name:

*Site Address:

*Latitude:

*Longitude:

*Site elevation:

*Inlet description, placement and height above ground:

*Classification (i.e., by land use: urban (commercial/residential), suburban, regional/rural, local source oriented):

*Emissions information in vicinity of site (~2 km):

Estimate of population density within site region:

Available GIS data for the site/region:

Photographs providing panoramic views:

Measurement characterization (required[#] for each measurement parameter reported – important to understand the quality of individual pollutant measurements)

- *Measurement parameter: (e.g., NO₂)
- *Instrumentation manufacturer:
- *Principal of operation:
- *Instrument time resolution and operational averaging time:
- *User averaging time and averaging period:
- *Date and time stamp (e.g., start and stop times, LST, GMT, required for hourly data):
- *Data validation flags^a (meaning “indicators”, see example below):
- *Concentration units (e.g., µg/m³, ppm, ppb):
- *Missing values reported as (e.g., -999, NA, other):
- *Calibration method (e.g., NO₂ traceable certified gas standard):
- *Frequency of calibration (e.g., zero and span checks once a day, multi-point calibrations once a week):

Measurement accuracy: Method of Determination:
Measurement precision: Method of Determination:
Measurement detection limit (DL, sometimes referred to as MDL, LDL, LOD):
Reporting of DLs (may be coupled to flagging scheme):
External audit frequency (e.g., once or twice a year): Date of last audit:
Completeness criteria (e.g., summarized by flagging criteria):

- *SOP available: (i.e., in your possession)
- *QA documentation/protocols available (i.e., in your possession):

[#]Each team will try its best to obtain the information required as much as possible, and report it if it is available.

^aFor example

- Valid value*
- V1 *Valid value but comprised wholly or partially of below detection limit data*
- V2 *Valid estimated value*
- V3 *Valid interpolated value*
- V4 *Valid value despite failing to meet some QC or statistical criteria*
- V5 *Valid value but qualified because of possible contamination (e.g., pollution source, laboratory contamination source)*
- V6 *Valid value but qualified due to non-standard sampling conditions (e.g., instrument malfunction, sample handling)*
- V7 *Valid value but set equal to the detection limit (DL) because the measured value was below the DL*
- M1 *Missing value because no value is available*
- M2 *Missing value because invalidated by data originator*
- H1 *Historical data that have not been assessed or validated*

Monitoring network characterization (important to understanding how well a set of monitoring sites reflect regional population exposures)

There are a variety of routine data analyses that can be performed to better understand the representativeness of the monitoring site with respect to local source orientation, spatial, and temporal characteristics as well as the spatial homogeneity of measurement parameters across the monitoring network. These analyses will provide information to help assess the quality of pollutant exposure estimates in the study region based on the network data. Some examples are presented below, but are certainly not all-inclusive.

In addition to basic summaries of air quality and meteorological data providing statistics on data completeness; daily, monthly or yearly mean, max, min, and std; monthly/seasonal distributions; and the identification of acute air pollution episodes and variety of standard data analyses should be considered to demonstrate spatial and temporal representativeness of the measurement sites: For example: 1) perform site-to-site correlation analyses to establish spatial homogeneity of primary and secondary pollutants and potential impacts of local source emissions; 2) analyze diurnal pattern of pollutants (those with hourly data) to assess the influence of local source emission patterns, boundary layer dynamics and the production of secondary pollutants on the individual measurement sites; and 3) analyze for week-day versus week-end differences in pollutant.

Annex C: Standardized sample of data for multi-city PAPA project

city	date	NO ₂	PM ₁₀	time	temp	hum	day_wk	hol	influ	all.all	all.card
HK	01/01/96	94.42910	77.94594	1	16.5	54	1	1	1	122	103
HK	02/01/96	122.78653	91.92738	2	17.5	63	2	0	1	107	86
HK	03/01/96	120.53335	125.59167	3	18.2	56	3	0	1	96	79
HK	04/01/96	59.64616	96.22601	4	17.4	59	4	0	1	107	80

Variable name:

city	BK: Bangkok, HK: Hong Kong, SH: Shanghai, WH: Wuhan
date of death	dd/mm/yy
NO ₂	daily average NO ₂
PM ₁₀	daily average PM ₁₀
temp	temperature in Celsius, 1 decimal place
hum	relative humidity in percentage
day_wk	dummy variables for days the week 1- Monday 2-Tuesday...6-Saturday; Sunday = reference
hol	public holiday 0-No 1-Yes
influ	influenza epidemics 0- No 1- Yes
all.all	all-natural cause all ages
all.card	cardiovascular diseases all ages

Notes

1. Please specify the terms included in the CORE model for each outcome, the degrees of freedom and the order of AR used, for example in HK:

$$\log(\text{all.all}) = S(\text{time}, 5 \text{ df/year}) + S(\text{temp}, 3) + S(\text{hum}, 3) + \text{factor}(\text{day_wk}) + \text{hol} + \text{influ}$$

2. Other cities may not use the same variables as that of HK so please add/delete the appropriate variables in the database accordingly.

3. Code NA for missing values.

Annex D: Log relative risk (RR) of mortality per 1 µg/m³ for city: _____ Period: _____

Cause of mortality	Pollutant	Lag													
		0		1		2		3		4		0-1		0-4	
		log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error
All causes All ages	NO ₂ SO ₂ PM ₁₀ O ₃														
Respiratory All ages	NO ₂ SO ₂ PM ₁₀ O ₃														
Cardiovascular All ages	NO ₂ SO ₂ PM ₁₀ O ₃														
All causes 65+	NO ₂ SO ₂ PM ₁₀ O ₃														

Note: Figures should be given in 9 decimal places

Annex E: Log relative risk (RR) of mortality per 1 µg/m³ for PM₁₀ with co-pollutant for city: _____ Period: _____

Cause of mortality	Co-Pollutant	Lag													
		0		1		2		3		4		0-1		0-4	
		log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error	log RR	std error
All causes All ages	PM ₁₀ +NO ₂ PM ₁₀ +SO ₂ PM ₁₀ +O ₃														
Respiratory All ages	PM ₁₀ +NO ₂ PM ₁₀ +SO ₂ PM ₁₀ +O ₃														
Cardiovascular All ages	PM ₁₀ +NO ₂ PM ₁₀ +SO ₂ PM ₁₀ +O ₃														
All causes 65+	PM ₁₀ +NO ₂ PM ₁₀ +SO ₂ PM ₁₀ +O ₃														

Note: Figures should be given in 9 decimal places

Annex F

Table 1: Selected environmental factors (Hong Kong data given as example)

Environmental factors	Hong Kong (1996)
Population (millions)	6.2
Area (Km ²)	1092
Climate:	Subtropical, with rain and tropical cyclones in the summer months
Mean January/July temperatures (deg C)	16/29
Rainfall per year	224 cm, most falling in the summer months
Topography	Peninsula with offshore islands
Life style	
Smoking rates (15 or older)	Male 26.7%; female 3.1% ¹
Regular alcohol consumers (at least once per week) (25-74 yrs)	Male 20.0%; female 2.0% ²
Dietary intake	Energy from fat 29%; protein 18%; carbohydrate 53% ² Daily cholesterol intake <300 mg ² ; male 33%, female 64%
Health Care System	Primary care services provided mainly by private sectors (85%) Hospital services provided mainly by public sectors (86%)
Median size of private dwellings	40.0-69.9 m ²
GNP per capita (US\$)	US\$24,061 per capita (1996 data)
Leading causes of death	(1996 data) 1. Malignant neoplasms 31.3% 2. Heart diseases 15.8% 3. Cerebrovascular disease 10.7% 4. Pneumonia, all forms 10.6% 5. Injury and poisoning 5.1%

¹ Census and Statistics Department. Social data collected via the general household survey.

² Janus ED, Cockram CS, Fielding R, Hedley AJ, Ho P, Lam KSL, Lam TH, Lau CP, Lo M, Lo SC, Ma PL, Masarei JRL, Tai YT, Tomlinson B, Wong SP, Woo JLF. Hong Kong Cardiovascular Risk Factor Prevalence Study 1995 – 1996. Hong Kong: HK Cardiovascular Risk Factor Prevalence Study Steering Committee, 1996, 145pp. ISBN 962-8310-0

Table 2: Selected health and air pollution statistics (Hong Kong data given as example)

Health variable	Hong Kong (1996)
Population < 15 yrs and > 64 yrs	18.9%; 10.0%
Infant Mortality Rate (per 1000 live births)	4.0‰
Age standardized mortality ¹	
From all causes	3.7‰
From respiratory diseases	0.7‰
From cardiovascular diseases	0.9‰
Emergency admissions for respiratory diseases	
Age standardized rate (per 1,000 population) ¹	12.9‰
Age distribution (%)	
0-14 years	33%
15-64 years	22%
64+ years	45%
Emergency admissions for cardiovascular diseases	
Age standardized rate (per 1,000 population)	5.8‰
Age distribution (%)	
0-14 years	2%
15-64 years	37%
64+ years	61%
Sources of pollutant emissions	(1997 data including TSP)
PM ₁₀	
Traffic	61.3% #
Industry	5.9% †
Power generation	32.50%
NO _x	
Traffic	41.1% #
Industry	7.5% †
Power generation	45.40%
SO ₂	
Traffic	13.8% #
Industry	20.8% †
Power generation	65.40%
Composition of PM ₁₀	(1996 data)
NO ₃ ⁻	5.40%
NH ₄ ⁺	4.30%
C	54.00%
SO ₄ ⁻	17.00%
PM _{2.5} in PM ₁₀	68.20%

vehicle, marine vessel, aircraft

† fuel combustion, cement plant

¹ Census and Statistics Department. Social data collected via the general household survey. Special Topics Report No. 20.

Table 3: Summary statistics of daily concentrations of pollutants ($\mu\text{g}/\text{m}^3$) and meteorological measurements

Pollutant	City	Season	Concentration (in $\mu\text{g}/\text{m}^3$)						
		(Warm/Cool)	Min.	1 st Qu.	Median	Mean	3 rd Qu.	Max.	SD
NO ₂	HK	(50.8/ 66.3)	10.3	45.0	56.3	58.5	69.2	167.5	20.1
SO ₂	HK	(19.5/16.2)	1.4	9.6	14.7	17.8	22.2	109.3	12.2
PM ₁₀	HK	(40.9/62.4)	14.2	31.8	45.5	51.6	66.8	189.0	25.3
O ₃	HK	(32.9/39.1)	2.0	41.0	69.0	73.7	98.0	314.0	40.5

Meteorological measure	City	Season	Meteorological						
		(Warm/Cool)	Min.	1 st Qu.	Median	Mean	3 rd Qu.	Max.	SD
Temperature (°C)	HK	(27.2/20.1)	6.9	19.8	24.7	23.7	27.8	33.8	4.9
Humidity (%)	HK	(81.0/74.9)	27.0	74.0	79.0	77.9	84.0	97.0	10.0

HK team: warm season April – September; cool season October – March