Association between Air Pollution and General Outpatient Clinic Consultations for Upper Respiratory Tract Infections in Hong Kong

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Abstract

Background and Objectives: Many studies have shown the adverse effects of air pollution on respiratory health, but few have examined the effects of air pollution on service utilisation in the primary care setting. The aim of this study was to examine the association between air pollution and the daily number of consultations due to upper respiratory tract infections (URTIs) in general outpatient clinics (GOPCs) in Hong Kong.

Methods: Daily data on the numbers of consultations due to URTIs in GOPCs, the concentrations of major air pollutants, and the mean values of metrological variables were retrospectively collected over a 3-year period (2008–2010, inclusive). Generalised additive models were constructed to examine the association between air pollution and the daily number of consultations, and to derive the relative risks and 95% confidence intervals (95% CI) of GOPC consultations for a unit increase in the concentrations of air pollutants.

Results: The mean daily consultations due to URTIs in GOPCs ranged from 68.4 to 253.0 over the study period. The summary relative risks (and 95% CI) of daily consultations in all GOPCs for the air pollutants PM₁₀, NO₂, O₃, and SO₂ were 1.005 (1.002, 1.009), 1.010 (1.006, 1.013), 1.009 (1.006, 1.012), and 1.004 (1.000, 1.008) respectively, per 10 μg/m³ increase in the concentration of each pollutant.

Conclusion: Significant associations were found between the daily number of consultations due to URTIs in GOPCs and the concentrations of air pollutants, implying that air pollution incurs a substantial morbidity and increases the burden of primary health care services.

Introduction

Most epidemiological time series studies on air pollution focus on hospital admissions and mortality as health outcomes. [1–6] These outcomes represent, respectively, serious morbidity and the ultimate health consequence of air pollution. Illnesses seen in primary health care settings, by contrast, form the much wider base of the ‘pyramid’ of air pollution-related diseases, but are much less studied.

Respiratory diseases are very common in all age groups and generate a major demand on health care services worldwide. Acute respiratory infections represent one of the most common reasons for seeking medical attention in the primary health care setting. [7] A recent cross-sectional morbidity study in Hong Kong revealed that 26.4% of outpatient consultations were due to upper respiratory tract infections [8].

Gaseous air pollutants such as sulphur dioxide (SO₂), ozone (O₃), and nitrogen dioxide (NO₂) have been shown to cause irritation and constriction of the large airways. [9] However, only a few studies have examined the association between air pollution and the daily number of consultations in the primary health care sector. [10–13] One reason was the lack, in most countries, of routinely collected data on primary care service utilisation in both private and public sectors; hence, data might need to be collected prospectively. For example, in a previous study we conducted in Hong Kong, we invited 13 private general practitioners (GPs) to manually record the daily number of patients consulted for respiratory diseases. We used these data to examine the association between the number of GP consultations and the concentration of air pollutants [13].

In Hong Kong, primary health care is provided by both the private general practitioner clinics and the public general outpatient clinics (GOPCs). The GOPCs network covers all districts
in Hong Kong, and provides primary care services mainly for the socially disadvantaged, while middle- to high-income groups often prefer private GP clinics for their primary care needs. Proportionately, more elderly patients and those with chronic diseases attend the GOPCs, whereas more patients with acute health problems consult GPs in private clinics. The GOPCs are heavily subsidised by the government; the charge per consultation in these clinics (HK$45 or ~US$6) is around a quarter of the median charges in private clinics, which range from US$19 to US$26. [14] The Hospital Authority (HA), a Hong Kong government-funded 'statutory board’, manages the public GOPC network, and since 1999, medical records in these clinics have progressively been computerised [15].

The aim of this study is to examine the effects of air pollution on the frequency of consultations for upper respiratory tract infections (URTIs) in the public primary care clinics. We retrospectively collected data on daily consultations due to URTIs, at the GOPCs located in two of seven geographically-defined hospital and clinic districts: Kowloon peninsula – a flat, densely populated urban area. The other two, part of the Kowloon West Cluster, which covers the Kowloon peninsula – a flat, densely populated urban area. The two other, part of the Kowloon West Cluster, were located in the north-western ‘new towns’ of Kwai Tsing and Tsuen Wan which, besides being residential, also have a container terminal and an industrial estate, respectively. Data were retrospectively collected from 1 January 2008 to 31 December 2010. [15] Four monitoring stations of the Hong Kong Government’s Environmental Protection Department were matched to the five GOPCs according to their geographic locations; one of the monitoring stations served both GOPC 2 and GOPC 3 (Figure 1).

Four pollutants were regularly monitored in all of the monitoring stations. These were: nitrogen dioxide (NO₂), sulphur dioxide (SO₂), ozone (O₃), and particulates with an aerodynamic diameter less than 10 μm (PM₁₀). Data regarding hourly concentration of these pollutants was obtained for the corresponding 3-year period as the clinical data (2008–2010) from the Hospital Reporting System of the Hospital Authority, for five of the HA’s GOPCs. Three of the GOPCs were in the Kowloon Central Cluster, which covers the Kowloon peninsula – a flat, densely populated urban area. The other two, part of the Kowloon West Cluster, were located in the north-western ‘new towns’ of Kwai Tsing and Tsuen Wan which, besides being residential, also have a container terminal and an industrial estate, respectively. Data were retrospectively collected from 1 January 2008 to 31 December 2010. [15] Four monitoring stations of the Hong Kong Government’s Environmental Protection Department were matched to the five GOPCs according to their geographic locations; one of the monitoring stations served both GOPC 2 and GOPC 3 (Figure 1).

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Materials and Methods

Data

This is a retrospective time series study. We identified ‘upper respiratory tract infection’ by the diagnostic code R74, defined as ‘URI (head cold)/rhinitis, not otherwise classified’ in the Revised Edition of the International Classification of Primary Care 2 (ICPC-2), prepared by the World Organization of National Colleges, Academies, and Academic Associations of General Practitioners/Family Physicians ( WONCA). [16] Under this classification system, R74 excludes specific diagnostic labels such as acute and chronic sinusitis (R75), acute tonsillitis (R76), acute laryngitis/tracheitis/croup (R77), acute bronchitis/bronchiolitis (R78), and influenza (R80). Data on the number of daily visits for URTIs (R74) were extracted from the Clinical Data Analysis & Reporting System of the Hospital Authority, for five of the HA’s GOPCs. Three of the GOPCs were in the Kowloon Central Cluster, which covers the Kowloon peninsula – a flat, densely populated urban area. The other two, part of the Kowloon West Cluster, were located in the north-western ‘new towns’ of Kwai Tsing and Tsuen Wan which, besides being residential, also have a container terminal and an industrial estate, respectively. Data were retrospectively collected from 1 January 2008 to 31 December 2010. [15] Four monitoring stations of the Hong Kong Government’s Environmental Protection Department were matched to the five GOPCs according to their geographic locations; one of the monitoring stations served both GOPC 2 and GOPC 3 (Figure 1).

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Statistical Modelling

A generalised additive model, using the Poisson distribution with a log-link function, was used to construct a core model for each of the five GOPCs. [18] In brief, each model regressed the daily numbers of the URTIs consultations on several variables: time (day), day of the week, daily mean temperature and humidity, and a holiday indicator. To adjust for the potential confounding effect of influenza on the number of URTIs consultations, we used a dichotomous variable to indicate the weeks during which the number of influenza consultations exceeded the 75th percentile for the study period. This method has been used in time series studies of air pollution and hospital admissions for respiratory illnesses. [19] The estimated weekly numbers of influenza were obtained from the Centre for Health Protection, Hong Kong SAR Government (www.chp.gov.hk). We used penalised smoothing splines [20,21] to adjust for seasonal patterns and long-term trends in daily consultations, temperature, and relative humidity, with degrees of freedom (df) selected a priori, based on previous studies. [22,23] Specifically, we used 7 df per year for time trends, 6 df for temperature and 3 df for humidity [19].

The quasi-likelihood method was used to correct for over-dispersion. [18] To minimise autocorrelation, which would bias the standard errors, we specified that the absolute values of the partial autocorrelation function for the model residuals had to be <0.1 for the first 2 lag days. [24] When these criteria were not met, we added autoregressive terms for the outcome variable to the core model, up to a maximum of three autoregressive terms.

Linear effects of all the air pollutants for the same day (lag 0) up to 3 lag days (lag 3) were tested in each model and the best lag for each pollutant at the GOPC was chosen as the one that yielded the largest t-value. We conducted all analyses using the MGCV package in R [25] and expressed the results as the relative risks (RRs) of visits for URTIs in each GOPC for every 10 μg/m³ increase in the concentrations of all four pollutants. The best lag RRs for each pollutant, obtained from individual GOPCs, were then combined using random effects models. [26] Ethics approval was obtained for conducting this study from the Research Ethics Committee, Kowloon West Cluster, Hospital Authority (Ref: KW/EX-11–137). Our study did not involve any patient’s personal information.

Results

Daily Consultations at GOPC

Table 1 shows summary statistics of the consultations due to URTIs, at the five GOPCs, over the study period. From 2008 to 2010, the total number of consultations was 617,240, with mean daily consultations ranging from 68.4 to 253.0. The district-specific demographic information for each GOPC is also shown.

Descriptive Statistics for Air Pollutants

Table 2 shows the mean, median, and quartile values of the daily air pollutant concentrations measured at each monitoring station throughout the study. During this period, the mean daily temperature and humidity in Hong Kong were 23.3°C (SD = 5.2) and 78.1% (SD = 11.1) respectively. Table 3 shows the Pearson’s correlations between the air pollutants, listed by each monitoring station.
Relative Risk of Daily Consultation

The individual relative risks (RRs) of consultation due to URTIs by GOPC, and the summary RRs for all GOPCs (per 10 $\mu g/m^3$ increase in the concentrations of each air pollutant) are shown in Table 4. The RRs for NO$_2$ in individual clinics were consistently significant. For PM$_{10}$, the RRs were significant in three out of five clinics while the RRs for O$_3$ were significant in four out of five clinics. For SO$_2$, none of the RRs in individual clinics were significant, although all were above unity. Statistically significant summary RRs were found for NO$_2$, PM$_{10}$, and O$_3$, while the combined RR for SO$_2$ was marginally significant ($p = 0.060$). The summary relative risks (with 95% confidence intervals) from all GOPC for NO$_2$, PM$_{10}$, O$_3$, and SO$_2$ were 1.005 (1.002, 1.009), 1.010 (1.006, 1.013), 1.009 (1.006, 1.012) and 1.004 (1.000, 1.008) respectively, per 10 $\mu g/m^3$ increase in the concentration of each air pollutant.

Discussion

While air pollution has been extensively researched with regard to its association with mortality and hospital admissions, studies...
reporting its effects on primary care consultations are scarce.\[11,13,27–30\] This time series study is one of the few that investigate air pollution's effects on primary health care service utilisation in the public sector. We found significant positive associations between three air pollutants – namely, NO2, O3, and PM10 (from zero to three lag days) – and the daily number of consultations for URTIs at outpatient clinics in Hong Kong. The combined RRs for NO2, O3, and PM10 (at 1.010, 1.009 and 1.005 respectively) for visits to public clinics herein investigated were substantially lower than their corresponding RRs reported for private GP visits in Hong Kong (at 1.030, 1.024 and 1.020 respectively) in our previous study in 2006.\[13\] One possible explanation is that the GOPCs services required patients to register either by walk-in or by phone, with daily quotas placed on the number of consultations. Because of the much lower prices charged by the GOPCs compared to that charged by the private sector GPs, the waiting time for patients attending GOPCs could be much longer than that for the latter.\[31\] Therefore, it is plausible that to reduce waiting time, patients with more severe URTIs may have consulted private GPs or even the accident and emergency departments of hospitals. This spillage of patients into alternative services could then result in the smaller RRs found at the GOPCs in this study. This would explain the findings in this study that the ‘response’ or ‘health outcome’ to a unit increase in the concentration of air pollutants, as GOPCs visits, was lower than consultations to private GPs. The lack of a significant association with SO2 could be explained by the relatively low concentrations of SO2 in Hong Kong. Levels of SO2 in three of the four stations were within the air quality guidelines of 20 μg/m3 recommended by the World Health Organization.\[9\] By contrast, the mean concentrations of NO2 and PM10 in all stations were much higher than their annual air quality guidelines.

The lag times in both Hong Kong studies were similar, ranging from zero to three lag days. In a GP study in London, significant RRs for SO2 and PM10 were reported for specific diseases (allergic rhinitis and asthma) and in different age groups for URTIs, as the 10th to the 90th percentile change in air pollutant concentrations, from zero to 3 lag days.\[27,28\] This makes comparison of RRs difficult. Ostro reported similar associations for PM10 and O3 with URTIs or lower respiratory tract infections (LRTIs) among children of different age groups in Santiago, Chile.\[29\] In an ambulatory care study in Atlanta, Georgia, in the USA, Sinclair and Toltsma found weak but significant associations between PM and consultations for asthma and LRTIs. They reported a longer

### Table 2. Summary statistics of the four air pollutants in the four monitoring stations from 1 January 2008 to 31 December 2010.

| Station          | Pollutant | Mean (SD) (μg/m³) | Median (μg/m³) | Quartile (μg/m³) |
|------------------|-----------|-------------------|----------------|------------------|
| Station 1 for GOPC 5 | NO2       | 62.7 (20.1)       | 58.5           | 48.2, 73.2       |
|                  | PM10      | 48.7 (28.9)       | 41.9           | 28.8, 62.9       |
|                  | O3        | 30.8 (19.6)       | 26.4           | 14.1, 43.8       |
|                  | SO2       | 19.8 (13.5)       | 17.2           | 10.7, 25.1       |
| Station 2 for GOPC 4 | NO2       | 64.9 (21.8)       | 59.7           | 49.6, 75.7       |
|                  | PM10      | 47.8 (27.4)       | 42.0           | 29.3, 62.1       |
|                  | O3        | 30.5 (20.3)       | 27.2           | 13.2, 43.6       |
|                  | SO2       | 23.6 (19.9)       | 15.3           | 8.1, 36.9        |
| Station 3 for GOPC 2 & 3 | NO2       | 67.5 (22.0)       | 66.6           | 50.8, 79.7       |
|                  | PM10      | 49.1 (29.9)       | 42.8           | 27.9, 64.0       |
|                  | O3        | 28.3 (19.1)       | 23.6           | 12.8, 40.0       |
|                  | SO2       | 16.6 (14.4)       | 11.9           | 7.3, 20.8        |
| Station 4 for GOPC 1 | NO2       | 60.8 (20.3)       | 56.2           | 47.1, 70.9       |
|                  | PM10      | 49.0 (31.8)       | 42.6           | 28.9, 63.9       |
|                  | O3        | 33.4 (21.9)       | 30.5           | 14.0, 48.5       |
|                  | SO2       | 16.4 (16.3)       | 10.3           | 6.9, 17.8        |

Remark: ‘Missing’ indicates that at least one pollutant measurement was missing that day.

### Table 3. Correlation between pollutants by monitoring station.

| Station          | Pollutant | NO2   | PM10  | O3    | SO2   |
|------------------|-----------|-------|-------|-------|-------|
| Station 1 for GOPC 5 | NO2       | 1     | 0.58**| 0.24**| 0.37**|
|                  | PM10      | 1     | 0.45**| 0.21**|       |
|                  | O3        | 1     | -0.22**|       |       |
|                  | SO2       | 1     |       |       |       |
| Station 2 for GOPC 4 | NO2       | 1     | 0.60**| 0.14**| 0.27**|
|                  | PM10      | 1     | 0.39* | 0.06* |       |
|                  | O3        | 1     | -0.46*|       |       |
|                  | SO2       | 1     |       |       |       |
| Station 3 for GOPC 2 & 3 | NO2       | 1     | 0.61**| 0.34**| 0.38**|
|                  | PM10      | 1     | 0.46**| 0.26**|       |
|                  | O3        | 1     | -0.07**|       |       |
|                  | SO2       | 1     |       |       |       |
| Station 4 for GOPC 1 | NO2       | 1     | 0.50**| 0.14**| 0.36**|
|                  | PM10      | 1     | 0.42**| 0.15**|       |
|                  | O3        | 1     | -0.22**|       |       |
|                  | SO2       | 1     |       |       |       |

*p<0.05; **p<0.01.

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and PM10 all had significant effects on daily visits to clinics due to consultation behaviour across different cities. Differences in lag time of 3 to 5 days. [30] Differences in lag days may have been reported elsewhere [35–38].

Hwang et al. reported that carbon monoxide (CO), NO2, SO2, and PM10 all had significant effects on daily visits to clinics due to association between air pollution and primary care utilisation. Besides time series studies, spatial studies have also reported the association between air pollution and primary care utilisation. Hwang et al. reported that carbon monoxide (CO), NO2, SO2, and PM10 all had significant effects on daily visits to clinics due to LRTIs, based on small area design and hierarchical modelling of data from 50 communities in Taiwan. [12] Oiamo et al. used a community health survey on GP access and utilisation in Sarnia, Ontario, in Canada, and data on spatial differences in air pollutant concentrations, to demonstrate their relationships. [32] A time series study that took place over the 2008 Olympic Games in Beijing showed a significant reduction in outpatient visits for asthma during the air pollution control period, during which traffic and industrial emissions were restricted. [33] This provided strong evidence of a cause-effect relationship between air pollution and respiratory illnesses in an outpatient setting.

Gieniewiczki and Jasperi have suggested a potential mechanism linking exposure to environmental air pollutants to their adverse health effects – including those effects related to respiratory infections. Pollutants could induce oxidative stress induced by exposure to air pollutants may enhance the morbidity of an infection through an increased inflammatory response. Potential mechanisms of individual pollutants have been reported elsewhere [35–38].

A major strength of our study is the large number of consultations (which increases the study’s power) and the reliability of the data sources, as all GOPCs data of the Hospital Authority are stored in one computerised database. In addition, we have a comprehensive network of air quality monitoring stations in different districts of the city. There are several limitations to our study results. First, as our study area was limited to one region of the city, and our GOPCs visitors belonged to the lower social class, selection bias is a possibility. Secondly, misclassification of the respiratory infections is a potential problem. For instance, in an outpatient setting, some LRTIs such as acute bronchitis or influenza might be wrongly coded as URTIs. This would have resulted in wider confidence intervals of the RR.

Upper respiratory tract infections should include R74 to R77 in the ICPC-2 codes. Owing to logistical constraints in the acquisition of daily data, we were only able to download one diagnostic code from the system. A check on the annual data (which could be accessed more easily) showed that the total number of cases coded as R75–77 was about 1% of the cases coded as R74. The mean daily number of the former group ranged from 0.9 to 2.6 cases in each of the five clinics, whereas the corresponding mean daily number of cases coded as R74 ranged from 68–253. Hence, we believe that our findings would not deviate much if we had included all the URTI codes.

Furthermore, all patients attending one clinic were assigned the same level of exposure to air pollutants according to data from the nearest monitoring station. In reality, individual exposure could be quite different from the ambient pollution concentration. We cannot rule out the possibility that some patients living in one district would use GOPCs in another district, because the distances between some clinics are fairly short. Hence, as in other ecological studies, the misclassification of patients’ true exposure to air pollution is a potential source of error that is difficult to assess. Nonetheless, the data on air pollutants show little variation measured in all monitoring stations. Moreover, PM10 are more relevant because of their effects on the upper respiratory tract.

### Table 4. Relative risks and 95% CI of the visits to five GOPCs for upper respiratory tract infections (URTIs), per 10 μg/m³ increase in the concentration of air pollutants.

| Clinic | NO2 | PM10 | O3 | SO2 |
|--------|-----|------|----|-----|
| GOPC 1 | 1.007 [lag 0 day] | 1.007 [lag 1 day] | 1.010 [lag 1 day] | 1.001 [lag 0 day] |
|        | (1.000, 1.013)* | (1.004, 1.010)* | (1.004, 1.016)* | (0.992, 1.009) |
| GOPC 2 | 1.014 [lag 0 day] | 1.005 [lag 0 day] | 1.003 [lag 1 day] | 1.014 [lag 0 day] |
|        | (1.000, 1.029)* | (0.998, 1.013) | (0.988, 1.018) | (0.998, 1.031) |
| GOPC 3 | 1.013 [lag 0 day] | 1.011 [lag 3 days] | 1.015 [lag 1 day] | 1.010 [lag 3 days] |
|        | (1.004, 1.023)* | (1.006, 1.017)* | (1.004, 1.025)* | (0.999, 1.022) |
| GOPC 4 | 1.010 [lag 3 days] | 1.005 [lag 3 days] | 1.010 [lag 1 days] | 1.002 [lag 0 day] |
|        | (1.004, 1.015)* | (1.001, 1.009)* | (1.004, 1.016)* | (0.996, 1.009) |
| GOPC 5 | 1.010 [lag 0 day] | 0.999 [lag 3 days] | 1.010 [lag 3 days] | 1.003 [lag 0 day] |
|        | (1.002, 1.017)* | (0.995, 1.003) | (1.003, 1.018)* | (0.993, 1.014) |
| Combined | 1.010 | 1.005 | 1.009 | 1.004 |
|        | (1.006, 1.013)* | (1.002, 1.009)* | (1.006, 1.012)* | (1.000, 1.008) |

*p < 0.05; *p = 0.06.

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Conclusion

Our results showed a significant association between the concentrations of several air pollutants and the daily number of GOPCs consultations due to URTIs in Hong Kong. These findings provide further evidence that air pollution is a major public health problem. The number of consultations in primary care represents much higher than hospital admissions and deaths. Air pollution thus incurs a substantial burden to health care services in an urban community.

References

1. Atkinson RW, Anderson HR, Sunyer J, Ayres J, Baccini M, et al. (2001) Acute effects of particulate air pollution on respiratory admissions: results from APHEA 2 project. Air Pollution and Health: a European Approach. Am J Respir Crit Care Med 164: 1860–1866.
2. Samet JM, Dominici F, Curriero FC, Kouris-Blazos A, Zeger SL. (2000) Fine particulate air pollution and mortality in 20 U.S. cities, 1987–1994. N Engl J Med 343: 1742–1749.
3. Katsouyanni K, Touloumi G, Spix C, Schwartz J, Balducci F, et al. (1997) Short-term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. Air Pollution and Health: a European Approach. BMJ 314: 1658–1663.
4. Schwartz J (1999) Air pollution and hospital admissions for heart disease in eight U.S. counties. Epidemiology 10: 17–22.
5. Brenner SA, Anderson HR, Atkinson RW, McMichael AJ, Strachan DP, et al. (1999) Short-term associations between outdoor air pollution and mortality in London 1992–4. Occup Environ Med 36: 237–244.
6. Kan H, Chen B (2003) Air pollution and daily mortality in Shanghai: a time-series study. Arch Environ Health 58: 360–367.
7. WHO WHO (2004) Respiratory Care in Primary Care Services – A Survey in 9 countries. World Health Organization: 121.
8. Lo YYC, Mercer SW, Fong DYT, Lee A, Lam TP (2011) Patient morbidity and management patterns of community-based primary health care services in Hong Kong. Hong Kong Medical Journal 17: 7.
9. WHO WHO (2006) WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Global update 2005. Summary of risk assessment. Geneva, Switzerland: World Health Organization.
10. Chang CJ, Yang HH, Chang CA, Tsai HY (2012) Relationship between air pollution and outpatient visits for non-specific conjunctivitis. Invest Ophthalmol Vis Sci 53: 429–433.
11. Hajat S, Anderson HR, Atkinson RW, Haines A (2002) Effects of air pollution on general practitioner consultations for upper respiratory diseases in London. Occup Environ Med 59: 294–299.
12. Hwang JS, Chan CC (2002) Effects of air pollution on daily clinic visits for lower respiratory tract illness. Am J Epidemiol 155: 1–10.
13. Wong TW, Tam W, Tak Sun Yu I, Wun YT, Wong AH, et al. (2006) Association between air pollution and general practitioner visits for respiratory diseases in Hong Kong. Thorax 61: 583–589.
14. Yam CH, Liu S, Huang OH, Yeo EK, Griffiths SM (2011) Can vouchers make a difference to the use of private primary care services by older people? Experience from the healthcare reform programme in Hong Kong. BMC Health Serv Res 11: 253.
15. Cheung NT, Fung KW, Wong KC, Cheung A, Cheung J, et al. (2001) Medical informatics–the state of the art in the Hospital Authority. Int J Med Inform 62: 115–119.
16. World Organization of National Colleges and Academies of Academic Associations of General Practitioners/Family Physicians (1998) ICPQC-2 : international classification of primary care. Oxford; New York: Oxford University Press x, 190 p.
17. Duffy ME (2006) Handling missing data: a commonly encountered problem in research. Clin Nurse Spec 20: 273–276.
18. Haste T, Tibshirani R (1995) Generalized additive models for medical research. Stat Methods Med Res 4: 157–196.
19. Qiu H, Yu TT, Tian L, Wang X, Tse LA, et al. (2012) Effects of coarse particulate matter on emergency hospital admissions for respiratory diseases: a time-series analysis in Hong Kong. Environ Health Perspect 120: 572–576.
20. Hout S, Larrieu S, Pascal L, Blanchard M, Declercq C, et al. (2008) Short-term associations between fine and coarse particles and hospital admissions for cardiorespiratory diseases in six French cities. Occup Environ Med 65: 544–551.
21. Kan H, London SJ, Chen G, Zhang Y, Song G, et al. (2007) Differentiating the effects of fine and coarse particles on daily mortality in Shanghai, China. Int J Environ Res Public Health 33: 376–384.
22. Bell MI, Ebius K, Peng RD, Walker J, Samet JM, et al. (2008) Seasonal and regional short-term effects of fine particles on hospital admissions in 202 US counties, 1999–2005. Am J Epidemiol 168: 1301–1310.
23. Peng RD, Chang HH, Bell MJ, McDermott A, Zeger SL, et al. (2008) Coarse particulate matter air pollution and hospital admissions for cardiovascular and respiratory diseases among Medicare patients. JAMA 299: 2172–2179.
24. Wong CM, Vichit-Vadakan N, Kan H, Qian Z. (2008) Public Health and Air Pollution in Asia (PAPA): a multicity study of short-term effects of air pollution on mortality. Environ Health Perspect 116: 1195–1202.
25. Wood SN (2006) Generalized additive models : an introduction with R. Boca RatonFL: Chapman & Hall/CRC. xvii, 391 p.
26. Fleiss JL (1995) The statistical basis of meta-analysis. Stat Methods Med Res 2: 121–145.
27. Hajat S, Haines A, Atkinson RW, Brenner SA, Anderson HR, et al. (2001) Association between air pollution and daily consultations with general practitioners for allergic rhinitis in London, United Kingdom. Am J Epidemiol 153: 704–714.
28. Hajat S, Haines A, Goubrat SA, Atkinson RW, Anderson HR (1999) Association of air pollution with daily GP consultations for asthma and other lower respiratory conditions in London. Thorax 54: 597–605.
29. Ostro BD, Eskeland GS, Sanchez JM, Feyzioglu T (1999) Air pollution and health effects: A study of medical visits among children in Santiago, Chile. Environ Health Perspect 107: 69–73.
30. Sinclair AH, Toloba D (2004) Associations and lags between air pollution and acute respiratory visits in an ambulatory care setting: 23-month results from the aerosol research and inhalation epidemiological study. J Air Waste Manage Assoc 54: 1212–1218.
31. Ng LY, Kam CW, Ng PTK, Chong SYC, Shek JKP, et al. (2009) What are the major factors influencing patients’ decision in queuing up for registration in a General Out-Patient Clinic attached to a regional hospital? The Hong Kong Practitioner 31: 10.
32. Osano TH, Luginaah IN, Atori DO, Gorey KM (2011) Air pollution and general practitioner access and utilization: a population based study in Saria, `Chemical Valley’, Ontario. Environ Health 10: 71.
33. Li Y, Wang W, Kan H, Xu X, Chen B (2010) Air quality and outpatient visits for asthma in adults during the 2008 Summer Olympic Games in Beijing. Sci Total Environ 408: 1226–1227.
34. Ciencewicki J, Jaspers I (2007) Air pollution and respiratory viral infection. Inhal Toxicol 19: 1135–1146.
35. Rahman I, MacNee W (2000) Oxidative stress and regulation of glutathione in lung inflammation. Eur Respir J 16: 534–554.
36. Reit M, Jennen P, Halliwell B (1998) Sulphite enhances peroxynitrite-dependent alpha1-antiproteinase inactivation. A mechanism of lung injury by sulphur dioxide? FEBS Lett 423: 231–234.
37. Scappellato ML, Lotti M (2007) Short-term effects of particulate matter: an inflammatory mechanism? Crit Rev Toxicol 37: 461–487.
38. Uysal N, Schapira RM (2003) Effects of ozone on lung function and lung diseases. Curr Opin Pulm Med 9: 144–150.

Author Contributions

Conceived and designed the experiments: WWST, TWW LN SYSW KKLK AH SW. Analyzed the data: WWST TWW LN SYSW KKLK. Wrote the paper: WWST TWW LN SYSW KKLK AH SW.