Table 8. Time-Series Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Bladen WA. 1983. Relationship between acute respiratory illness and air pollution in an Indian industrial city. J Air Pollut Control Assoc 33:226–227.	Time series	Bombay, India	1989	2980 patients records of respiratory illness	PM, SO_2, CO, HC	Acute respiratory illness	Air pollution from SO_2, PM, CO, and HC were markedly associated with acute respiratory illness. This finding was especially strong from November to February when pollution concentrations were higher due to thermal inversions.
Chang G, Pan X, Xie X, et al. 2003. Time-series analysis on the relationship between air pollution and daily mortality in Beijing [in Chinese]. Wei Sheng Yan Jiu 32:565–568.	Time series	Beijing, China	1998–2000	Residents in 8 districts	TSP, PM_{10}, SO_2, NO_x, CO	Daily cause-specific mortality (RespD, CVD, CBVD, CHD, COPD)	Airborne levels of CO, SO_2, NO_x, and PM_{10} each correlated significantly with mortality, especially from RespD, CVD, CBVD, CHD, and COPD. TSP levels were associated with RespD.
Chang GQ, Wang LG, Pan XC. 2003. Study on the associations between ambient air pollutant and hospital outpatient visitor emergency room visit in Beijing [in Chinese]. Chin J School Doctor 17:295–297.	Time series	Beijing, China	1998–2000	Children	TSP, PM_{10}, SO_2, NO_x, CO	Daily unscheduled hospital outpatient and ER visits for colds, pneumonia, and bronchitis	When CO, SO_2, NO_x, or PM_{10} increased by 100 $\mu g/m^3$, visits for colds, bronchitis, and pneumonia also increased by 1–8%.
Chang JH, Hsia YU, Chen WL. 2002. Effect of air pollution on daily clinic treatments for respiratory cardiovascular diseases in central Taiwan, 1997–1999 [in Chinese]. Taiwan Occupational Medicine Journal. 9:111–120.	Time series	Central Taipei,China	1997–1999	Residents	PM_{10}, SO_2, NO_2, O_3	Hospital admission for RespD and CVD	The increase of O_3, NO_2, PM_{10}, and SO_2 levels were significantly associated with the increase of respiratory admissions, but not with cardiovascular disease admissions.
Chen YS, Sheen PC, Chen ER, et al. 2004. Effects of Asian dust storm events on daily mortality in Taipei, Taiwan. Environ Res 95:151–155.	Time series (episode)	Taipei City, Taipei,China	1995–2000	2.6 million residents	PM_{10}, SO_2, NO_2, CO, O_3	Daily mortality for all-cause, RespD, and CVD	The analysis results suggested a likely casual relationship between dust storm and mortality for all-cause, CVD, and RespD.
Chew FT, Goh DYT, Ooi BC, et al. 1999. Association of ambient air-pollution levels with acute asthma exacerbation among children in Singapore. Allergy 54:320–329.	Time series	Singapore	1990–1994	2.7 million people	TSP, SO_2, NO_2, O_3	Morbidity: acute asthma, emergency room visits	Although overall levels of air pollution were generally within World Health Organization quality guidelines, higher levels of SO_2 and TSP were associated with more frequent emergency room visits for children 3–12 yr but not for those 13–21 yr.
Cho B, Choi J, Yum YT. 2000. Air pollution and hospital admissions for respiratory disease in certain areas of Korea. J Occup Health 42:185–191.	Time series	Ulsan, Daejeonm suwon, South Korea	1996	3.6 million people	TSP, SO_2, NO_2, CO, O_3	Morbidity: hospitalizations for RespD (bronchial asthma, COPD, bronchitis)	In a single-pollutant model, respiratory admissions were highly correlated with CO in a residential area and with NO_2 and CO in a mixed residential-industrial area. In a multipollutant model, TSP and CO were significantly associated in the residential area, but CO alone was significantly associated in the industrial area.

* Last updated June 2005.

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Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Cropper ML, Simon NB, Alberini A, et al. 1997. The health effects of air pollution in Delhi, India. PRD Working Paper 1860 (unpublished). New Ideas in Pollution Regulation, World Bank, Washington DC. Available from www.worldbank.org/nipr/work_paper/1860/index.htm.	Time series	Delhi, India	1991–1994	–	TSP, SO_2, NO_x	Mortality (nontraumatic deaths, RespD and CVD deaths)	Mortality for ages 5–64 yr was significantly associated with TSP. The authors note, however, that reducing TSP by 100 μg/m^3 led to a 2.3% increase in deaths compared with a 6% increase reported for other countries. They attributed the difference to differences in expected life span.
Dai H, Song W, Gao X, et al. 2004. Study on relationship between ambient PM_{10}, $PM_{2.5}$ pollution and daily mortality in a district in Shanghai [in Chinese]. Wei Sheng Yan Jiu 33:293 297.	Time series	Shanghai, China	2002–2003	1.24 million residents in a district of Shanghai	PM_{10}, $PM_{2.5}$	Daily mortality for all causes, cardiovascular causes, and respiratory causes	Each increase of 10 μg/m^3 in PM_{10} and $PM_{2.5}$ was associated with 0.53% and 0.85% increase of daily mortality, respectively.
Dong JW, Xu XP, Chen YD, et al. 1995. Relationship between air pollution and daily mortality in urban district of Beijing [in Chinese]. J Hyg Res 24:212–214.	Time series	Beijing, China	1990–1991	1.4 million residents	TSP, SO_2	Daily mortality	Increased mortality was associated with increased SO_2 and TSP levels, especially for people ≥ 65 yr. The effects of TSP on cardiovascular mortality and SO_2 on respiratory mortality were greater, particularly for people ≥ 65 yr.
Dong JW, Xu XP, Dockery DW, et al. 1996. Association of air pollution with unscheduled outpatient visits in Beijing Longfu Hospital, 1991 [in Chinese]. Zhonghua Liu Xing Bing Xue Za Zhi 17:13–16.	Time series	Beijing, China	1991	All unscheduled patient visits	TSP, SO_2	Unscheduled outpatient and surgery visits	Airborne TSP level was significantly related to the number of unscheduled nonsurgical outpatient visits, but not related to the number of unscheduled surgical visits. SO_2 was significantly associated with pediatric visits only.
Emmanuel SC. 2000. Impact to lung health of haze from forest fires: The Singapore experience. Respirology 5:175–182.	Time series (episode)	Singapore	1997	–	PM_{10}, SO_2, NO_2, CO, O_3, Haze	Outpatient visits and mortality for RespD, accident, and emergency visit	During several months of haze from forest fires, an increase of PM_{10} from 50 to 150 μg/m^3 was significantly associated with increases in outpatient visits for upper respiratory illness (12%), asthma (19%), and rhinitis (26%). Neither hospital admissions nor mortality increased significantly.
Gao J, Xu XP, Chen YD, et al. 1993. Relationship between air pollution and mortality in Dongcheng and Xicheng Districts, Beijing [in Chinese]. Zhonghua Yu Fang Yi Xue Za Zhi 27:340–343.	Time series	Beijing, China	1989	All deaths	TSP, SO_2	Total mortality, RespD mortality	Logarithmic levels of airborne SO_2 were significantly associated with daily number of deaths (especially from bronchitis, COPD, and cor pulmonale).
Ha EH, Lee JT, Kim H, et al. 2003. Infant susceptibility of mortality to air pollution in Seoul, South Korea. Pediatrics 111:284–290.	Time series	Seoul, South Korea	1995–1999	1045 children (1 mo–1 yr), 67,597 people (2–64 yr), 100,316 elders (> 65 yr)	TSP, SO_2, NO_2, CO, O_3	Daily total and respiratory mortality (excluding accidental deaths)	CO level was significantly associated with respiratory mortality, especially for individual 2–64 yr.

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Hedley AJ, Wong CM, Thach TQ, et al. 2002. Cardiorespiratory and all-cause mortality after restrictions on sulphur content of fuel in Hong Kong: An intervention study. Lancet 360:1646–1652.	Time series	Hong Kong, China	1985–1995	~75% Hong Kong residents (15–64 yr, >65 yr, and all ages)	PM_{10}, SO_2, NO_2, O_3	Monthly mortality (all, RespD, CVD)	A one-weekend restriction to < 0.5% sulfur content in fuel oil for power plants and motor vehicles in Hong Kong led to an immediate fall in SO_2 levels. In the following year, seasonal mortality was substantially reduced for total deaths, RespD, and CVD causes, resulting in a gain in life expectancy. By 3–5 years later, the pattern had returned to expected.
Honda Y, Nitta H, Ono M. 2003. Low level carbon monoxide and mortality of persons aged 65 or older in Tokyo, Japan, 1976–1990. J Health Sci 49:454–458.	Time series	Tokyo, Japan	1976–1990	Elderly people (≥ 65 yr)	SO_2, NO_2, NO, CO, oxidant	All-cause mortality	Higher CO levels were associated with increased mortality rates in persons ≥ 65 yr, even when the CO levels were lower than the National Air Quality Standard in Japan.
Hong YC, Lee JT, Kim H, et al. 2002. Air pollution: A new risk factor in ischemic stroke mortality. Stroke 33:2165–2169.	Time series	Seoul, South Korea	1991–1997	10.6 million people	TSP, SO_2, NO_2, CO, O_3	Daily stroke mortality (both hemorrhagic and ischemic)	TSP, SO_2, NO_2, CO, and O_3 levels were significantly associated with mortality from ischemic stroke but not from hemorrhagic stroke.
Hong YC, Lee JT, Kim H, et al. 2002. Effects of air pollutants on acute stroke mortality. Environ Health Perspect 110:187–191.	Time series	Seoul, South Korea	1995–1998	10.6 million people	PM_{10}, SO_2, NO_2, O_3, CO	Mortality: stroke	Estimated increase in stroke mortality was 1.5% for each interquartile increase in PM_{10} and ozone in the same day. Stroke mortality increased 3.1% for NO_2, 2.9% for SO_2, and 4.1% for CO in a 2-day lag for each interquartile increase in single-pollutant models. The elderly and women were more susceptible to particulate pollutants.
Hong YC, Leem JH, Ha EH, et al. 1999. PM_{10} exposure, gaseous pollutants, and daily mortality in Inchon, South Korea. Environ Health Perspect 107:873–878.	Time series	Inchon, South Korea	1995–1996	2.4 million residents	PM_{10}, SO_2, NO_2, CO, O_3	Mortality: CVD, RespD, and total deaths not due to accidents or violence	PM_{10} was significantly associated with total, CVD, and RespD mortality. SO_2 and CO were significantly associated with RespD mortality. O_3 was not significantly or linearly associated with any cause of mortality. The combined index of PM_{10}, NO_2, SO_2, and CO seemed to better explain exposure–response relation.
Hong YC, Leem JH, Ha EH. 1999. Air pollution and daily mortality in Inchon, Korea. J Korean Med Sci 14:239–244.	Time series	Inchon, South Korea	1995	2.2 million residents	TSP, PM_{10}, SO_2, NO_2, CO, O_3	Daily mortality (total)	Total daily mortality increased 1.2% for each 10 μg/m^3 increase in 6-day moving average of TSP and 1.2% for each 10 μg/m^3 increase in 5-day moving average of PM_{10}. Associations between gaseous pollutants and total mortality were not significant. The relative risk of death increased at particulate levels well below the Korean Air Quality Standard at that time.

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Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Hwang JS, Chan CC. 2002. Effects of air pollution on daily clinic visits for lower respiratory tract illness. Am J Epidemiol 155:1–10.	Time series	50 townships and city districts, Taipei,China	1998	–	PM_{10}, SO_2, NO_2, CO, O_3	Daily clinic visits for lower respiratory tract illness	The number of daily clinic visits was associated with current day levels of NO_2, CO, SO_2, and PM_{10}. People > 65 yr were most susceptible. Estimated pollution effects decreased as exposure lag increased.
Kan H, Chen B. 2003. Air pollution and daily mortality in Shanghai: a time-series study. Arch Environ Health 58:360–367.	Time series	Shanghai, China	2000–2001	Residents	PM_{10}, SO_2, NO_2	Daily mortality for all-nonaccidental-cause, CVD, and COPD	Each 10 μg/m^3 increase in PM_{10}, SO_2, and NO_2 corresponded to a significant increase in relative risk of mortality from all causes of 0.3%, 1.4%, and 1.5%, respectively.
Kan H, Jia J, Chen B. 2003. Acute stroke mortality and air pollution: new evidence from Shanghai, China. J Occup Health 45:321–323.	Time series	Zhabei District of Shanghai, China	2001–2002	2426 stroke deaths	PM_{10}, SO_2, NO_2	Daily stroke mortality	Each 10 μg/m^3 increase in PM_{10}, SO_2, and NO_2 corresponded to 0.8%, 1.7%, and 2.9% increase in relative risk of stroke mortality, respectively.
Kan H, Jia J, Chen B. 2004. The association of daily diabetes mortality and outdoor air pollution in Shanghai, China. J Environ Health 67:21–26.	Time series	Shanghai, China	2001–2002	Residents in a district of Shanghai	PM_{10}, SO_2, NO_2	Daily diabetes mortality	Each 10 μg/m^3 increase in PM_{10}, SO_2, and NO_2 corresponded to an increase of relative risk of diabetes mortality of 0.6%, 1.1%, and 1.3%, respectively, in Shanghai.
Kim H, Kim Y, Hong YC. 2003. The lag-effect pattern in the relationship of particulate air pollution to daily mortality in Seoul, Korea. Int J Biometeorol 48:25–30.	Time series	Seoul, South Korea	1995–1999	Residents	PM_{10}	Daily mortality for nonaccidental deaths, respiratory disease, cardiovascular disease, and cerebrovascular disease	Respiratory mortality was more affected by air pollution level on the day of death, whereas cardiovascular deaths were more affected by the previous day's air pollution level. Cerebrovascular deaths were simultaneously associated with the air pollution levels of the same day and the previous day.
Kim H, Lee JT, Hong YC, et al. 2004. Evaluating the effect of daily PM– variation on mortality. Inhal Toxicol 16(Suppl 1):55–58.	Time series	Seoul, South Korea	1997–2001	Residents	PM_{10}	Daily mortality	Daily mortality was associated with daily mean and daily deviation of PM_{10} level. Each 42.11 μg/m^3 increase of daily mean level of PM_{10} was associated with 2.1% increase of additional daily mortality. Each 11.93 μg/m^3 increase in daily standard deviation of PM_{10} was also associated with 2.5% increased risk of death.
Kim SY, Lee JT, Hong YC, et al. 2004. Determining the threshold effect of ozone on daily mortality: an analysis of ozone and mortality in Seoul, Korea, 1995–1999. Environ Res 94:113–119.	Time series	Seoul, South Korea	1995–1999	–	PM_{10}, SO_2, NO_2, O_3, CO	Daily mortality for nonaccidental and nonviolent causes	Each 21.5 ppb increase of daily 1-h maximum ozone, lagged by 1 day, was associated with a 2.6% increase in relative risk in total mortality in a linear model, and a 3.4% increase in a threshold model.

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Knöbel HH, Chen CJ, Liang KY. 1995. Sudden infant death syndrome in relation to weather and optimetrically measured air pollution in Taiwan. Pediatrics 96:1106–1110.	Time series	Taipei,China	1981–1991	Infants (1 wk–1 yr)	PM_{10}, SO_2, CO, PSI, visibility	Daily mortality from sudden infant death syndrome or suffocation	Mortality from sudden infant death syndrome was 3.3 times greater in the lowest category of visibility on day of death than in the highest category; rate ratio was 3.4 for the average visibility during 9 days before death. Adjusting for covariates increased rate ratios to 3.8 and 5.1, respectively.
Kwon HJ, Cho SH, Chun Y, et al. 2002. Effects of the Asian dust events on daily mortality in Seoul, Korea. Environ Res 90:1–5.	Time series (episode)	Seoul, South Korea	1995–1998	Residents	Asian dust event (PM_{10}, SO_2, NO_2, CO, O_3)	Daily mortality for all causes, cardiovascular diseases, and respiratory diseases	Asian dust events were positively, but not significantly, associated with respiratory and CVD mortality. The relationship was stronger in people ≥ 65 yr.
Kwon HJ, Cho SH, Nyberg F, et al. 2001. Effects of ambient air pollution on daily mortality in a cohort of patients with congestive heart failure. Epidemiology 12:413–419.	Time series, Case crossover	Seoul, South Korea	1994–1998	1807 patients with congestive heart failure and admission history	PM_{10}, SO_2, NO_2, CO, O_3	Mortality (nonaccidental)	An increase in PM_{10} was associated with an increase in mortality from congestive heart failure. CO, NO_2, SO_2, and O_3 were also associated with mortality from congestive heart failure.
Kwon HJ, Cho SH.1999. Air pollution and daily mortality in Seoul [in Korean]. Korean J Prev Med 32:191–199.	Time series	Seoul, South Korea	1991–1995	Residents	TSP, SO_2, NO_2, O_3	Daily mortality for all causes, cardiovascular diseases, and respiratory diseases	Daily death counts were associated with ambient level of O_3 1-day before, NO_2 1-day before, TSP 2-days before, and SO_2 2-days before. This effect was stronger in persons ≥ 65 yr. The effect on respiratory and cardiovascular deaths was also stronger than all-cause deaths.
Lee JT, Kim H, Cho YS, et al. 2003. Air pollution and hospital admissions for ischemic heart diseases among individuals 64+ years of age residing in Seoul, Korea. Arch Environ Health 58:617–623.	Time series	Seoul, South Korea	1997–1999	Residents (> 64 yr)	PM_{10}, SO_2, NO_2, CO, O_3	Hospital admissions for ischemic heart disease	Daily ambient SO_2 level was significantly associated with ischemic heart disease–related hospital admissions of the elderly during summer months, as well as with daily variation of air pollutant levels.
Lee JT, Kim H, Hong YC, et al. 2000. Air pollution and daily mortality in seven major cities of Korea, 1991–1997. Environ Res 84:247–254.	Time series	7 cities in South Korea	1991–1997	22.8 million residents	TSP, SO_2, O_3	Mortality (nonaccidental)	Increase of 50 ppb of SO_2 corresponded to 1–12% more deaths depending on the city assessed. Estimated risk of death by SO_2 was unaffected by adding TSP and O_3 to the model. All ambient levels were below Korea's standards at that time.
Lee JT, Kim H, Song H, et al. 2002. Air pollution and asthma among children in Seoul, Korea. Epidemiology 13:481–484.	Time series	Seoul, South Korea	1997–1999	6436 children (< 15 yr)	PM_{10}, SO_2, NO_2, CO, O_3	Hospitalization due to asthma attack	Estimated relative risk of asthma hospitalization was 1.07 for PM_{10}, 1.11–1.16 for SO_2, NO_2, O_3, and CO. In the multipollutant models, control for other pollutants did not change the estimated effect for O_3 or NO_2.

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Lee JT, Lee SI, Shin D, et al. 1998. Air particulate matters and daily mortality in Ulsan, Korea [in Korean]. Korean J Prev Med 31:82–90.	Time series	Ulsan, South Korea	1991–1994	Residents	TSP, SO_2	Daily mortality for non-accidental cause	Each 100 μg/m³ increase of TSP was associated with a 3% increase in mortality.
Lee JT, Shin D, Chung Y. 1999. Air pollution and daily mortality in Seoul and Ulsan, Korea. Environ Health Perspect 107:149–154.	Time series	Seoul, Ulsan, South Korea	1991–1995	10.8 million people in Seoul, 0.8 million in Ulsan	TSP, SO_2, O_3	Mortality (nonaccidental)	An increase of 50 ppb of SO_2 significantly increased all-cause mortality by 12–13%. A 50-ppb increase of O_3 increased all-cause mortality by 14% and 4.6%, respectively, in the 2 study cities.
Leem JH, Lee JT, Kim DG, et al.1998. Short-term effect of air pollution in hospital visits for respiratory disease in Seoul [in Korean]. Korean J Prev Med 10:333–342.	Time series	Seoul, South Korea	1995–1996	Residents	PM_{10}, O_3	Hospital visits for respiratory problems	A 50 μg/m³ increase of PM_{10} 2 days before and an 0.01 ppm increase of O_3 were associated with 11% and 8% increased risk of respiratory hospital visits, respectively.
Mott JA, Mannino DM, Alverson CJ, et al. 2005. Cardiorespiratory hospitalizations associated with smoke exposure during the 1997, Southeast Asian forest fires. Int J Hyg Environ Health 208:75–85.	Cohort, Time series (episode)	Kuching, Malaysia	1995–1998	Attendants of 7 hospitals	Forest fire smoke	Hospitalization for all causes, RespD, cardiorespiratory diseases, circulatory diseases, COPD, and asthma	Significant fire-related increases were observed in respiratory hospitalizations, especially those for COPD and asthma. Survival analyses indicated that persons > 65 yr with previous hospital admissions were significantly more likely to be rehospitalized for any cause, cardiorespiratory, and respiratory diseases during the post-fire period.
Odajima, H, Hirose T, Nishima S. 1995. Air pollution (NO_2, suspended particulate material) and the number of acute hospitalization of patients with asthmatic attack [in Japanese]. Arerugi 44:160–169.	Time series	Minami-ku, Jonan-ku Fukuoka, Japan	1988–1991	3661 patients with asthmatic attacks	SPM, NO_2	Hospital admission for asthmatic attack	SPM and NO_2 levels were associated with numbers of hospital admissions for athmatic attacks in children < 6 yr. There was no such association in children 7–20 yr.
Omori T, Fujimoto G, Yoshimura I, et al. 2003. Effects of particulate matter on daily mortality in 13 Japanese cities. J Epidemiol 13:314–322.	Time series	13 largest cities in Japan	1990–1994	Elderly residents (≥ 65 yr)	SPM	Daily mortality	Each 10 μg/m³ increase of SPM level was associated with increases in daily mortality for all causes (0.77%), for RespD (1.09%), and for CVD (0.91%).
Ostro B, Chestnut L, Vichit-Vadakan N, et al. 1999. The impact of particulate matter on daily mortality in Bangkok, Thailand. J Air Waste Manage Assoc 49:PM100–PM107.	Time series	Bangkok, Thailand	1992–1995	More than 6 million people	PM_{10}	Mortality (all except accidental, homicidal, suicidal)	PM_{10} was significantly associated with alternative measures of daily mortality. The results suggest relative risks consistent with or greater than those reported in most US studies: A 10 μg/m³ change in daily PM_{10} was associated with 1–2% increases in natural and CVD mortality and a 3–6% increase in RespD mortality.

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Pande JN, Bhatta N, Biswas D, et al. 2002. Outdoor air pollution and emergency room visits at a hospital in Delhi. Indian J Chest Dis Allied Sci 44:13–19.	Time series	New Delhi, India	1997–1998	More than 10 million people	TSP, SO_2, NO_x, CO	Morbidity (COPD, asthma, acute coronary event)	Emergency room visits for acute asthma, COPD, and coronary events increased by 21%, 25%, and 24%, respectively, on days with higher levels of pollution (CO, NO_x, SO_2).
Park H, Lee B, Ha EH, et al. 2002. Association of air pollution with school absenteeism due to illness. Arch Pediatr Adolesc Med 156:1235–1239.	Time series	Seoul, South Korea	1996-1999	1264 school-children	PM_{10}, SO_2, NO_2, CO, O_3	Illness-related school absenteeism	Exposures to PM_{10}, SO_2, and O_3, but not NO_2 were associated with illness-related absenteeism from elementary school.
Piver WT, Ando M, Ye F, et al. 1999. Temperature and air pollution as risk factors for heat stroke in Tokyo, July and August 1980–1995. Environ Health Perspect 107:911–916.	Time series	Tokyo, Japan	1980–1995	11.8 million residents	PM_{10}, NO_2, O_3	Heat stroke	Same-day daily maximum temperature and NO_2 concentrations were the most significant risk factors for heat stroke in all age groups of men and women. Men > 65 yr were most at risk for heat stroke.
Sastry N. 2002. Forest fires, air pollution, and mortality in southeast Asia. Demography 39:1–23.	Time series (episode)	Multiple cities in Malaysia	1997	All deaths	Forest fire smoke	Mortality	Smoke haze from widespread forest fires had a deleterious effect on the health of the population.
Sawaguchi T, Toro K, Sawaguchi A. 1997. Sudden infant death syndrome in relation to climatic temperature, climatic humidity and air pollution in Japan. Rom J Leg Med 5:21–24.	Time series	47 prefectures in Japan	1988–1994	–	SO_2, NO_2	Sudden infant death syndrome	No correlation was found between the incidence of sudden infant death syndrome and temperature, humidity, NO_2 level, or SO_2 level.
Shimizu S, Kagawa J, Ishiguro M. 2001. The association between emergency clinic visits for asthmatic attacks and fluctuating environmental factors [in Japanese]. Arerugi 50:612–620.	Time series	Yokohama, Japan	1990–1991	–	SPM, SO_2, NO_2, NO	Nocturnal emergency-room visits for asthmatic attack	The number of emergency-room visits for asthma attacks positively correlated with increasing levels of pollutants. When both humidity and temperature decreased, the degree of correlation between hospital visits and pollution increased.
Shinkura R, Fujiyama C, Akiba S. 1999. Relationship between ambient sulfur dioxide levels and neonatal mortality near the Mt. Sakurajima volcano in Japan. J Epidemiol 9:344–349.	Time series	Yamashita public health district of Kagoshima City, Japan	1978–1988	Residents	SO_2	Neonatal mortality	Increased ambient SO_2 level was associated with excess neonatal mortality. However, more studies are needed to elucidate the mechanisms of excess neonatal mortality and ambient SO_2 levels.
Tanaka H, Honma S, Nishi M, et al. 1998. Acid fog and hospital visits for asthma: An epidemiological study. Eur Respir J 11:1301–1306.	Time series	Kushiro, Japan	1992–1993	102 people with asthma (15–79 yr)	SPM, SO_2, NO_x, NO_2, NO, O_3, fog	Morbidity: asthma hospital visit	In nonatopic patients, fog, high O_3, and water vapor pressure, low day-to-day temperature differences, and low concentrations of atmospheric NO and NO_2 significantly contributed to increased hospital visits. In atopic patients, fog, high water vapor pressure, and low levels of atmospheric NO_2 and SO_2 contributed significantly to hospital visits.

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Tango T. 1994. Effect of air pollution on lung cancer: A Poisson regression model based on vital statistics. Environ Health Perspect 102(Suppl 8):41–45.	Time series	Tokyo, Japan	1972–1988	Women (40–79 yr) from 23 wards of Tokyo	SO_2, NO_2	Mortality: lung cancer	NO_2 was positively associated with the rate of increase in lung cancer mortality. The association with SO_2 was weaker.
Tseng RYM, Li CK, Spinks JA. 1992. Particulate air pollution and hospitalization for asthma. Ann Allergy 68:425–432.	Time series	Hong Kong, China	1983–1989	Hospital patients	TSP, RSP, SO_2, NO_2, NO_x, O_3	Hospital discharges for asthma	Quarterly mean TSP and hospital discharge rates were strongly correlated for children 1–4 yr, were inversely correlated for children 5–14 yr, and were uncorrelated for adults. No correlation was found for SO_2, O_3, RSP, NO_2, or NO_x.
Tseng RYM, Li CK. 1990. Low level atmospheric sulfur dioxide pollution and childhood asthma. Ann Allergy 65:379–383.	Time series	Hong Kong, China	1983–1987	13,620 childhood hospitalizations	TSP, RSP, SO_2, NO_2, NO, O_3	Asthma episodes	Hospitalizations of children for asthma compared with levels of SO_2, NO_2, NO, O_3, TSP, and RSP identified an inverse correlation of SO_2 with hospitalization.
Vajanapoom N, Shy CM, Neas LM, et al. 2002. Associations of particulate matter and daily mortality in Bangkok, Thailand. Southeast Asian J Trop Med Public Health 33:389–399.	Time series	Bangkok, Thailand	1992–1997	Residents	PM_{10}, visibility	Daily mortality for all causes (except for injury and poisoning), respiratory diseases, cardiovascular diseases, and other diseases	Increasing PM_{10} and decreasing visibility levels were independently associated with increasing daily mortality from non-external causes, cardiovascular, respiratory, and other diseases. The associations were stronger for respiratory diseases than for cardiovascular and other diseases and were stronger for persons ≥65 yr than for those in the younger age group.
Venners SA, Wang B, Peng Z, et al. 2003. Particulate matter, sulfur dioxide, and daily mortality in Chongqing, China. Environ Health Perspect 111:562–567.	Time series	Chongqing, China	1995	576,000 residents	$PM_{2.5}$, SO_2	Daily mortality (RespD, CVD, cancers, other)	When SO_2 increased by 100 μg/m^3, relative risks of mortality (lags 2 and 3), RespD mortality (lag 2), and CVD mortality (lag 3) also increased. The association of $PM_{2.5}$ and daily mortality was negative and nonsignificant. Rates of mortality due to cancer and other causes did not change. Estimated RespD and CVD mortality correlated with SO_2 even after controlling for $PM_{2.5}$.
Wong CM, Atkinson RW, Anderson HR, et al. 2002. A tale of two cities: Effects of air pollution on hospital admissions in Hong Kong and London compared. Environ Health Perspect 110:67–77.	Time series	Hong Kong, China and London, UK	1995–1997 (Hong Kong), 1992–1994 (London)	-	PM_{10}, SO_2, NO_2, O_3	Hospital admissions for asthma (15–64 yr), RespD (60 yr only), cardiac disease (all ages), IHD (all ages)	For respiratory hospital admissions, both cities showed positive associations with PM_{10}, NO_2, SO_2, and O_3 with slightly different lags. For cardiac admissions, both cities showed positive associations with PM_{10}, NO_2, and SO_2. Associations between NO_2 and O_3 were negative in London but positive in Hong Kong.

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Table 8. Time-Series Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Wong CM, Ma S, Hedley AJ, et al. 1999. Does ozone have any effect on daily hospital admissions for circulatory diseases? J Epidemiol Community Health 53:580–581.	Time series	Hong Kong, China	1994–1995	629,196 population (65 yr or older)	PM_{10}, SO_2, NO_2, O_3	Hospital admissions for RespD and CVD	Levels of NO_2, SO_2, O_3 and PM_{10} were significantly associated with hospital admissions for RespD, CVD, COPD, and heart failure. NO_2, O_3, and PM_{10} were significantly associated with admissions for asthma, pneumonia, and influenza. Significant positive interactions were found between NO_2, O_3, and PM_{10} and between O_3 and winter months. Patients ≥ 65 yr were at greater risk.
Wong CM, Ma S, Hedley AJ, et al. 2001. Effect of air pollution on daily mortality in Hong Kong. Environ Health Perspect 109:335–340.	Time series	Hong Kong, China	1995–1997	All residents	PM_{10}, SO_2, NO_2, O_3	Daily mortality (nonaccidental, CVD, RespD)	Ambient concentrations of NO_2, SO_2, and O_3 were associated with mortality from all nonaccidental causes, CVD, and RespD during the cool season, but not the warm season. PM_{10} was associated with RespD mortality only.
Wong GWK, Ko FWS, Lau TS, et al. 2001. Temporal relationship between air pollution and hospital admissions for asthmatic children in Hong Kong. Clin Exp Allergy 31:565–569.	Time series	Hong Kong, China	1993–1994	1217 children (<15 yr)	PM_{10}, SO_2, NO_2	Hospital admissions for asthma	Daily admissions for asthma increased significantly with increases in ambient NO_2, SO_2, and inhalable particles
Wong TW, Lau TS, Yu TS, et al. 1999. Air pollution and hospital admissions for respiratory and cardiovascular diseases in Hong Kong. Occup Environ Med 56:679–683.	Time series	Hong Kong, China	1994–1995	–	PM_{10}, SO_2, NO_2, O_3	Hospital admissions for CVD or CBVD	Daily hospital admissions for all causes of circulatory disease were associated with increased ozone with the strongest effect on patients with arrhythmias and heart failure.
Wong TW, Tam WS, Yu TS, et al. 2002. Associations between daily mortalities from respiratory and cardiovascular diseases and air pollution in Hong Kong, China. Occup Environ Med 59:30–35.	Time series	Hong Kong, China	1995–1998	Hong Kong residents	PM_{10}, SO_2, NO_2, O_3	Daily mortality (RespD; CVD and CBVD)	Levels of NO_2, SO_2, O_3, and PM_{10} were significantly associated with mortality from RespD and from IHD. In multipollutant analyses, PM_{10} was not associated with RespD or CVD mortality.
Xu X, Dockery DW, Christiani DC, et al. 1995. Association of air pollution with hospital outpatient visits in Beijing. Arch Environ Health 50:214–220.	Time series	Beijing, China	1990	–	TSP, SO_2	Hospital outpatient visits	The number of daily nonsurgical outpatient visits was significantly associated with SO_2 and TSP levels, especially in summer. This was true even though the mean SO_2 concentration in summer was only 17 μg/m^3.
Xu X, Gao J, Dockery DW, et al. 1994. Air pollution and daily mortality in residential areas of Beijing, China. Arch Environ Health 49:216–222.	Time series	Beijing, China	1994	1.5 million residents in 2 areas	TSP, SO_2	Daily mortality (all causes, CVD, cardiopulmonary disease, cancer)	SO_2 was significantly associated with total mortality (at levels below World Health Organization recommendations) and with COPD, CHD, cardiopulmonary, and CVD mortality. TSP was significantly associated only with COPD mortality. SO_2 and TSP were significant predictors of total mortality in summer, but in winter only SO_2 was a significant predictor.

* Last updated June 2005.

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Xu X, Li B, Huang H. 1995. Air pollution and unscheduled hospital outpatient and emergency room visits. Environ Health Perspect 103:286–289.	Time series	Beijing, China	1990	–	TSP, SO_2	Daily hospital outpatient and emergency visits	Results suggested an exposure–response relation between TSP and SO_2 and hospital outpatient visits both at high air pollution levels and at levels well below World Health Organization air quality standards.
Xu Z, Yu D, Jing L, et al. 2000. Air pollution and daily mortality in Shenyang, China. Arch Environ Health 55:115–120.	Time series	Shenyang, China	1992	3.1 million residents	TSP, SO_2	Daily mortality (all causes, CVD, cardiopulmonary disease, COPD, cancer)	High mean TSP (430 $\mu g/m^3$) and SO_2 (197 $\mu g/m^3$) levels were each positively associated with total daily mortality. TSP was also significantly associated with CVD mortality. SO_2 was positively associated with COPD mortality.
Ye F, Piver WT, Ando M, et al. 2001. Effects of temperature and air pollutants on cardiovascular and respiratory diseases for males and females older than 65 years of age in Tokyo, July and August 1980–1995. Environ Health Perspect 109:355–359.	Time series	Tokyo, Japan	July–Aug 1980–1995	Emergency transports (> 65 yr)	PM_{10}, SO_2, NO_2, CO, O_3	CVD (angina, cardiac insufficiency, hypertension, myocardial infarction) and RespD (asthma, acute and chronic bronchitis, pneumonia)	Concentrations of NO_2 or PM_{10} were associated with daily hospital emergency transports for angina, cardiac insufficiency, hyocardial infarction, asthma, acute and chronic bronchitis, and pneumonia for men and women.
Zhou YR, Zeng Q, Xu F. 1997 Relationships between air pollution and trend of admission case in Chongqing [in Chinese]. J Mod Prev Med 24:43–45.	Time series	Chongqing, China	1991–1992	Residents of 6 districts	TSP, SO_2, NO_x	Hospital admission for respiratory diseases, COPD, cancer, and injury	Ambient air pollution, especially TSP and SO_2, was associated with the COPD hospital admission.

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