Table 15. Mortality Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Browne DR, Husni A, Risk MJ. 1999. Airborne lead and particulate levels in Semarang, Indonesia and potential health impacts. Sci Total Environ 227:145–154.	Health impact	Semarang, Indonesia	1996–1997	1.3 million adults and children	TSP, airborne lead	Mortality (total, RespD)	Increased TSP near major roads resulted in an estimated 1.6% increase in total mortality and a 7.9% increase in RespD mortality.
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.
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.
Choi KS, Inoue S, Shinozaki R. 1997. Air pollution, temperature, and regional differences in lung cancer mortality in Japan. Arch Environ Health 52:160–168.	Ecologic	47 prefectures, Japan	1970–1990	All lung cancer deaths	NO_2, SO_2, traffic emissions	Lung cancer mortality (every 5 years)	Regional differences in age-adjusted lung cancer death rates were explained by NO_2 and temperature. Temperature increased the effect of NO_2 on lung cancer deaths compared with NO_2 alone in 1 region.
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.

* Last updated June 2005.

Table 15. Mortality Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
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.
Deb SK. 1998. Acute respiratory disease survey in Tripura in case of children below five years of age. J Indian Med Assoc 96:111–116.	Ecologic	Tripura, India	1992–1993	800 children (< 5 yr)	Ambient air pollution	Acute respiratory infection–related morbidity and mortality	Air pollution in the urban area was responsible for the higher incidence of acute respiratory illness in all age groups when compared with children in the relatively unpolluted rural area.
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.
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.
Han CZ, Guo Y, Jing JX, et al. 1995. A study on the relationship between malignant tumor mortality and environmental pollution in Beicun countryside of Datong City [in Chinese]. Zhonghua Liu Xing Bing Xue Za Zhi 16:101–104.	Ecologic	Datong, China	1985–1989	103 subjects, 30 controls	TSP, B*a*P	Tumor mortality, serum copper, and zinc levels	Greater levels of nitrate and nitrite in drinking water and airborne levels of B*a*P were associated with significantly higher levels of serum copper and zinc and significantly higher incidence of malignant tumor mortality compared with a control group.

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Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
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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Imai M, Yoshida K, Kitabatake M. 1986. Mortality from asthma and chronic bronchitis associated with changes in sulfur oxides air pollution. Arch Environ Health 41:29–35.	Cohort	Yokkaichi, Japan	1963–1983	260,000 residents	TSP, SO_2, photochemical oxidants	Mortality for bronchial asthma and chronic bronchitis	The fluctuation of annual mortality of bronchial asthma and chronic bronchitis seemed to follow the trend of air pollution levels. In the polluted area, mortality due to bronchial asthma in adults was higher when higher SO_2 levels were prevalent.
Jin LB, Qin Y, Xu Z et al. 1999. Association between air pollution and mortality in Benxi [in Chinese]. Chin J Public Health 15:211–212.	Ecologic	Benxi, China	1993–1994	667,553 people	TSP, SO_2	All-cause mortality, COPD, CVD, CBVD	Annual daily mean TSP concentrations varied from medium to high in three districts of Benxi, a major center for the iron and steel industry. With each 100 μg/m^3 increase in TSP, mortality from all causes, COPD, CVD, and CBVD were estimated to increase by 8% to 24%.
Joseph A, Ad S, Vastava A. 2003. PM(10) and its impacts on health—a case study in Mumbai. Int J Environ Health Res 13:207–214.	Health impact	Mumbai, India	1995–2000	General population	RSP	Mortality	The authors conclude that transfer of results from epidemiologic studies in developed countries can underestimate health effects in developing countries and should not be used for this purpose.
Kamat SR, Doshi VB. 1987. Sequential health effect study in relation to air pollution in Bombay, India. Eur J Epidemiol 3:265–277.	Cross section	Mumbai, India	1977–1979	4129 subjects	SPM, SO_2, NO_2	Respiratory morbidity; mortality (cardiac, respiratory, cancer)	Air pollution was related to several respiratory symptoms as well as an increase in mortality due to cardiac, respiratory, and malignant diseases.
Kan H, Chen B. 2003. A case-crossover analysis of air pollution and daily mortality in Shanghai. J Occup Health 45:119–124.	Case crossover	Shanghai, China	2000–2001	64,862 deaths	PM_{10}, SO_2, NO_2	Mortality (total, COPD, and CVD)	Conditional logistic regression identified increases in relative risk of death from COPD and CVD.
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.

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Kan HD, Chen BH, Chen CG, et al. 2004. An evaluation of public health impact of ambient air pollution under various energy scenarios in Shanghai, China. Atmos Environ 38:95–102.	Health impact	Shanghai, China	2010, 2020	Shanghai residents	Air pollution in various energy scenarios	Premature death, chronic bronchitis, respiratory hospital admission, cardiovascular hospital admission, outpatient visit (internal medicine, pediatrics), acute bronchitis, and asthma attack	Compared with best-case scenario, implementation of various energy scenarios could prevent 608 to 5144 and 1189 to 10,462 PM_{10}-related avoidable deaths in 2010 and 2020, respectively. Substantial decrease of morbidity would occur as well.
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 non-accidental 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.
Kitabatake M, Manjurul H, Feng Yuan P, et al. 1995. Trends of air pollution versus those of consultation rate and mortality rate for bronchial asthma in individuals aged 40 years and above in the Yokkaichi region [in Japanese]. Nippon Eiseigaku Zasshi 50:737–747.	–	Yokkaichi, Japan	–	Residents	Ambient air pollution	Consultation rate and mortality rate for bronchial asthma	–

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Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
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, 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.
Kwon HJ, Hong YC, Lee JT, et al. 2002. Effects of ambient air pollution on daily mortality in a cohort of patients with stroke in Seoul, Korea. Epidemiology 13:S170.	Case crossover	Seoul, South Korea	1994–2000	Patients with stroke	PM_{10}, SO_2, NO_2, CO, O_3	Daily mortality for all causes	Daily mortality in stroke patients was associated with the increased air pollution.
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, 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 nonaccidental cause	Each 100 $\mu g/m^3$ increase of TSP was associated with a 3% increase in mortality.
Lee JT, Schwartz J. 1999. Reanalysis of the effects of air pollution on daily mortality in Seoul, Korea: A case-crossover design. Environ Health Perspect 107:633–636.	Case crossover	Seoul, South Korea	1991–1995	12 million people	TSP, SO_2, O_3	Mortality (nonaccidental)	Increases in atmospheric SO_2 level were associated with increases in daily mortality across different analysis methods.

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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.
Lee YL, Shaw CK, Su HJ, et al. 2003. Climate, traffic-related air pollutants and allergic rhinitis prevalence in middle-school children in Taiwan. Eur Respir J 21:964–970.	Cross section	Taipei,China	1995–1996	331,686 middle-school children	PM_{10}, SO_2, NO_x, CO, O_3	Morbidity: allergic rhinitis	Physician-diagnosed allergic rhinitis associated with higher nonsummer temperatures and traffic-related air pollutants, including CO, NO_x, O_3.
Li H, Jin S, Shi S, et al. 1994. The trend of mortality of lung cancer and its association with air pollution [in Chinese]. Zhonghua Liu Xing Bing Xue Za Zhi 15:38–41.	Ecologic	Shandong Province, China	1985–1989	All deaths	TSP, SO_2, NO_x, BaP	Lung cancer mortality	Compared with 1970–1974, deaths from lung cancer were higher in 1985–1989. Correlational analyses attributed rate of lung cancer to air pollution.
Murata M, Takayama K, Fukuma S, et al. 1988. A comparative epidemiologic study on geographic distributions of cancers of the lung and the large intestine in Japan. Jpn J Cancer Res 79:1005 1016.	Ecologic	11 prefectures and 1 city (583 districts) in Japan	1975–1979	–	TSP, SO_2, NO_2, HC, traffic emissions	Morbidity and mortality for lung and colon cancer	Lung cancer was highly correlated with industrialization-related factors (such as localization of manufacturing industries, automobile traffic, and air pollution), whereas colon cancer was correlated with the population density of workers in the tertiary industries (such as services, trade, and government).
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 $\mu g/m^3$ 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 $\mu g/m^3$ change in daily PM_{10} was associated with 1–2% increases in natural and CVD mortality and a 3–6% increase in RespD mortality.
Pan BJ, Hong YJ, Chang GC, et al. 1994. Excess cancer mortality among children and adolescents in residential districts polluted by petrochemical manufacturing plants in Taiwan. J Toxicol Environ Health 43:117–129.	Ecologic	Kaohsiung, Taipei,China	1971–1990	Children (0–19 yr)	Petrochemical air pollution	Cancer death	Review of death certificates of children (0–19 yr) living near petrochemical and petroleum complexes revealed statistically significant excess deaths due to cancers at all sites when compared with national and local reference groups. Excess cancer deaths of bone, brain, and bladder were clustered in the 10–19 yr age group, who had been possibly exposed for a longer period.

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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.
Shima M, Adachi M. 2000. Effect of outdoor and indoor nitrogen dioxide on respiratory symptoms in schoolchildren. Int J Epidemiol 29:862–870.	Cross section	7 communities in Chiba prefecture, Japan	1991–1993	842 children (9–10 yr)	NO_2	Morbidity: respiratory symptoms	Questionnaire responses and other data revealed a significant association between wheeze and asthma and outdoor NO_2 levels, but no such association with indoor NO_2 concentration. The data did suggest that girls may be more susceptible to indoor NO_2 than boys are.
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.
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.
Tao X, Hong CJ, Yu S, et al. 1992. Priority among air pollution factors for preventing chronic obstructive pulmonary disease in Shanghai. Sci Total Environ 127:57–67.	Cross section	Shanghai, China	1978–1987	All deaths	IP, SO_2, indoor coal use	Mortality and morbidity (COPD, lung function, nonspecific immunologic function)	Of ambient SO_2, inhalable particles, and indoor use of coal, COPD mortality and morbidity as well as nonspecific immunologic compromise correlated most strongly with indoor use of coal.
Tsai SS, Huang GH, Goggins WB, et al. 2003. Relationship between air pollution and daily mortality in a tropical city: Kaohsiung, Taiwan. J Toxicol Environ Health 66:1341–1349.	Case crossover	Kaohsiung, Taipei,China	1994–2000	All nonaccidental deaths	PM_{10}, SO_2, NO_2, O_3, CO	RespD and circulatory mortality	No significant effects were found between PM_{10} and SO_2 levels and respiratory mortality.

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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, 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 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.
Xiao HP, Xiu Q, Xu ZY. 1990. Effects of air pollution on human respiratory disease in Shengyang [in Chinese]. Chinese J Public Health 65:195–198.	Cross section	Shengyang, China	1985	2615 adults (40–69 yr)	TSP, SO_2	Prevalence and mortality of RespD, hospital admissions	Ambient air pollution was associated with the increase of morbidity, hospital admission, mortality of respiratory diseases among people > 40 yr.
Xiao HP, Xu ZY. 1985. Air pollution and lung cancer in Liaoning Province, People's Republic of China. NCI Monogr 69:53–58.	Ecologic	Liaoning Province, China	1976–1978	Residents in 10 Liaoning cities	TSP, industrial pollution (including Cu, Zn)	Lung cancer mortality	Neighborhood air pollution indices correlated significantly with mortality rates in one city, and lung cancer rates were higher near point sources of industrial pollution. Little correlation was found between TSP levels and lung cancer in 10 cities.

* Last updated June 2005.

Table 15. Mortality Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
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.
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 μg/m^3) and SO_2 (197 μg/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.
Xu ZY, Brown L, Pan GW, et al. 1996. Lifestyle, environmental pollution and lung cancer in cities of Liaoning in northeastern China. Lung Cancer 14(Suppl 1):S149–S160.	Case control	Shenyang, China	1985–1988	1249 lung cancer patients, 1345 controls	Industrial air pollution	Lung cancer mortality	Risk was increased for all occupations in which there was exposure to dusts, with the highest risk seen among coke oven workers and fire-resistant brick makers. Significant dose–response patterns were observed among cumulative total dust, cumulative total B*a*P, and lung cancer.
Xu ZY, Liu Y, Yu D, et al. 1996. Effect of air pollution mortalities in Shenyang city [in Chinese]. Chin J Public Health 15:61–64.	Ecologic	Shenyang, China	1992	438,600 people	TSP, SO_2	All-cause mortality, COPD, CBVD, CVD, cancer, tuberculosis	Annual daily TSP means in 3 neighborhoods of low, medium, or high pollution were 361, 477, and 518 μg/m^3, respectively. The means for SO_2 were 64, 128, and 235 μg/m^3, respectively. The three neighborhoods differed in rates of mortality from all causes, COPD, CBVD, CVD, cancer, and tuberculosis.
Yang CY, Chang CC, Chuang HY, et al. 2004. Relationship between air pollution and daily mortality in a subtropical city: Taipei, Taiwan. Environ Int 30:519–523.	Case crossover	Taipei, Taipei,China	1994–1998	2.64 million residents	PM_{10}, SO_2, NO_2, CO, O_3	Daily mortality for all causes, respiratory diseases, and circulatory diseases	Effects were observed for NO_2 and CO levels on death due to respiratory disease, while weaker associations were observed for PM_{10}, SO_2, and O_3.
Yang CY, Cheng MF, Chiu JF, et al. 1999. Female lung cancer and petrochemical air pollution in Taiwan. Arch Environ Health 54:180–185.	Case control	Taipei,China	1990–1994	399 cases and 399 controls matched for sex, year of birth, and year of death	Petrochemical air pollution	Female lung cancer mortality	Women living in areas with a high level of petrochemical air pollution had a significantly higher risk of developing lung cancer than a group living in an area with low petrochemical air pollution.

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Table 15. Mortality Studies*

Citation	Design	Study Location	Study Period	Study Sample	Exposure	Health Outcome	Summary of Published Findings
Yang CY, Tsai SS, Cheng BH, et al. 2000. Female lung cancer mortality and sex ratios at birth near a petroleum refinery plant. Environ Res 83:33–40.	Cohort	Nantzu, Tsoying, Taipei,China	1971–1996	–	Petrochemical air pollution	Sex ratio, female lung cancer mortality	Standardized mortality ratios for female lung cancer revealed that lung cancer deaths rose gradually 30–37 years after introduction of the local petroleum refinery camp. The sex ratio was not affected.
Zhang J, Song H, Tong S, et al. 2000. Ambient sulfate concentration and chronic disease mortality in Beijing. Sci Total Environ 262:63–71.	Cohort	Beijing, China	1980–1992	Residents in 8 districts	TSP, SO_2, NO_x, CO, B*a*P, SO_4^{2-}	Cause-specific mortality (total, RespD, CBVD and CVD, malignant tumor)	Both current SO_4^{2-} level and the level 12 yr before death were significantly correlated with total mortality and mortality due to CVD, malignant tumor, and lung cancer. SO_4^{2-} levels did not correlate with mortality from RespD or CBVD.

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