1 [266]

POPE, C.A.III., BURNETT, R.T., THUN, M.J., CALLE, E.E., KREWSKI, D., ITO, K., & THURSTON, G.D.

Lung Cancer, Cardiopulmonary mortality, and long-term exposure to fine particulate air pollution

JAMA 2002; 287; 1132–1141

American Cancer Society cohort recruited in 1982. Analysis of over 500,000 people in an average of 51 metropolitan districts. Interesting data showing reductions in $PM_{2.5}$ from 1979–1983 and from 1999–2000, values ranging from 10 to 30 in the first period, and from 5 to 20 in the second. Nonparametric smoothed response functions shown for the three categories of diagnosis; conclude that for a 10 microgram/m^3 change in PM_{10}, all cause mortality increased by 4 percent; cardiopulmonary mortality increased by 6 percent, and lung cancer mortality increased by 8 percent. Ninety-five percent confidence levels of all indices of RR were above 1.0. Coarse particle fraction and TSP not consistently associated with mortality. Other pollutants considered were sulfate, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone. Numbers of metropolitan areas that could be considered varied with the different pollutants. Cox proportional hazards model with inclusion of a metropolitan-based random effects component in a two stage analysis. The continuous smoking variables included nine different indices (such as "current smokers years of smoking squared" and eight others). Controls also devised for educational level and occupational exposures. A two dimensional term was inserted to account for spatial trends. Higher regressions were noted in men than in women, and lower educational status was associated with higher risks. Risks in people who never smoked were also generally higher than in former or current smokers.

Authors conclude: "The findings of this study provide the strongest evidence to date that long-term exposure to fine particulate air pollution common to many metropolitan areas is an important risk factor for cardiopulmonary mortality."

The US EPA Draft Criteria Document (June 2002) makes these points about the new analysis: "(a); doubles the follow-up time from eight years to sixteen years, and triples the number of deaths: (b) expands the ambient air pollution data substantially, including two recent years of fine particle data, and adds data on gaseous co-pollutants: (c) improves statistical adjustment for occupational exposure; (d) incorporates data on dietary covariates believed to be important factors in mortality, including total fat consumption, and consumption of vegetables, citrus fruit, and high-fiber grains: and (e) uses recent developments in non-parametric spatial smoothing and random effects statistical models as input to the Cox Proportional hazards model."

2 [100]

BOBAK, M., & LEON, D.A.

The Effect of Air Pollution on Infant Mortality appears specific for respiratory causes in the postnatal period

Epidemiology 1999; 10; 666–670

All births registered in the Czech Republic between 1989 and 1991. For each infant death, 20 controls randomly selected from infants of the same sex born on the same day and alive when the case died. Exposure assigned as the arithmetic mean of all 24-hour air pollution measurements in the district of residence of each case and control for the period between the birth and death of the index case. 2,494 infant deaths. Respiratory deaths analyzed. Risk Rate ratios for a 50 microgram/m^3 increase in particles = 1.95; 1.74 for SO_2; and 1.66 for NO_2. Only particles showed a consistent association when all pollutants entered in one model. No evidence of an association between any pollutant and mortality from any other cause. Conclude: "the effects of air pollution on infant mortality are specific for respiratory causes in the postneonatal period, are independent of socioeconomic factors, and are not mediated by birth weight or gestational age."

The crude RR for SO_2 was 2.16; adjusted for socioeconomic was 1.94; adjusted for perinatal factors was 2.09; and adjusted for all covariates was 1.87. These values were higher than those for TSP. Similar RRs for NO_2 were 1.55; 1.71;; 1.60; & 1.78.

Respiratory deaths numbered about 133.

Important observations.

3 At Hubbard Brook Research Station in New Hampshire, where scientists have been studying acid rain since the experimental forest was established there in 1955. Researchers result that acid rain has leached roughly half of the calcium from forest soils, while sharply increasing levels of sulfur, nitrogen and a toxin, aluminum. Declines in red spruce, sugar maple and likely other forest species as well are linked to acid deposition. Hubbard Brook Research Foundation, *Acid Rain Revisited*, March, 2001, http://www.hubbardbrook.org/education/Glossary/AcidRain.pdf.

4 The acid rain provisions of the Clean Air Act Amendments of 1990 were intended to protect the acid-sensitive lakes and streams of northeastern Canada and the U.S. However, in 2002, 41 percent of lakes in the Adirondacks and nearly 15 percent of New England lakes remained acidic, and their recovery is hampered by the acidic anions slowly leaching from the soils." In spite of declining sulfate concentrations, some lakes and streams have been slow to recover. Their recovery is slowed by continuing acid deposition, the presence of nitrate in surface waters, the loss of soil's ability to neutralize excess acidity, the contribution of naturally occurring acid sources, and a lengthy lag time between deposition reduction and ecosystem recovery." U.S. Environmental Protection Agency, *Acid Rain Program 2001 Progress Report*, p. 37, http://www.epa.gov/airmarkets/cmprpt/arp01/2001report.pdf and *BioScience* [**51,** 180 (2001)]

In North and South Carolina, Tennessee and other states in the southeast, researchers have found circumstances mirroring those in the northeast. Streams are acidified in both the Shenandoah and Great Smoky Mountains National Parks. The loss of the capacity to neutralize acids in Shenandoah is said to be "ubiquitous." Trout embryo survival has fallen and, in one stream, fish survivorship dropped from 80 percent to 0 percent as acid neutralizing capacity fell. National Park Service, "Acid Deposition Impacts on Aquatic and Terrestrial Ecosystems," *Technical Information in Support of the Department of the Interior's Request for a Rule to Restore and Protect Air Quality Related Values*, http://www.aqd.nps.gov/ard/epa/.

5 One measure, for example, of the ability of lakes and streams to fend off the damage of acid rain is the acid neutralizing capacity (ANC) of soils which, in turn, is increased by the presence in soils of cations. If acid rain, snow and fog are not neutralized, they leach from the soil metals such as aluminum and lead, that are toxic to fish and trees. According to the EPA in its 2001 report on program progress, "Recovery, as shown by increasing acid neutralizing capacity (ANC) is occurring, especially in the Adirondacks and Pennsylvania ... However, levels of base cations, including calcium, magnesium and potassium, are not increasing; in fact, they are decreasing." U.S. Environmental Protection Agency, *Acid Rain Program 2001 Progress Report*, p. 37, http://www.epa.gov/airmarkets/cmprpt/arp01/2001report.pdf.

6 There are two separate sets of global temperature data maintained, one by the British Meteorological Office, the other by the Goddard Institute for Space Studies, which is an arm of the U.S. National Aeronautics and Space Administration (NASA). Both are based on data from different sets of temperature stations located throughout the world, and both agree that the highest temperatures on record have been in the decades of the 1980s and 1990s.

Five of the hottest years on record were during the decade of the 1980s. Record highs continued into 1990 and 1991, but were interrupted by the cooling effect from the massive 1991 explosion of Mount Pinatubo in the Philippines.

This event caused the injection of huge amounts of dust into the upper atmosphere, where it cooled the Earth by reflecting sunlight. When the dust settled out, the warming trend resumed: 1995 was the hottest year on record and 1991 through 1995 was the hottest five-year period ever, despite Pinatubo's cooling effect. More recently, 2004 was the fourth warmest on record, exceeded by 1998, 2002 and 2003. Climatic Research Unit, University of East Anglia and the United Kingdom Meteorology Office, http://www.cru.uea.ac.uk/cru/info/warming/

Increase in Soil Temperatures

As the Earth's surface warms, the warmth bleeds slowly downward, gradually heating the subsurface as well. The temperature of solid stone, frozen tundra or other impermeable materials changes only through conductance, unlike permeable soils, which can be

warmed or cooled as water or air percolate through. Thus, if the temperature rises beneath permafrost or in granite, it is because the surface air is warmer.

In the unpopulated wilderness of the Alaskan Arctic, where thousands of oil and gas exploration wells have been drilled, the U.S. Geological Survey (USGS) has examined temperatures deep beneath the surface and found that they have increased. The first USGS measuring station was South Barrow Number Three, roughly 13 miles from Point Barrow, the northernmost point in North America. There, researchers found a 2- to 4-degree-centigrade warming in the last century.

When this pioneering work was reported in 1986, it set off a global inquiry. In the past ten years, findings of increased subsurface soil temperature have come from boreholes in Cuba, Australia, Greenland, Russia, France, Finland, Italy, Africa, China, New Zealand, Central Europe and Albania. John Sass, "Climate Plumbs the Depths," *Nature* (February 7, 1991): 458 ***and*** personal communication, Arthur Lachenbruch on July 8, 1996.

Increase in Ocean Temperatures

Oceanographers and other scientists with the Spanish Institute of Oceanography in Madrid have measured temperature, salt content and a variety of other factors at 115 different Atlantic Ocean sites that were also surveyed in 1981 and 1957. They concluded that the ocean had not only "consistently warmed," but the warming was "remarkably uniform [and] surprisingly deep." The maximum warming, found at 1,100 meters depth, was occurring at a rate of 1_C per century, which the research team called "broadly consistent with model predictions of climate change due to increases in atmospheric CO_2 concentration." Gregoria Parrilla, et. al., "Rising Temperatures in the Subtropical North Atlantic Ocean Over the Past 35 Years," *Nature* (May 5, 1994): 48–51.

There have been similar findings in the Pacific Ocean. Scientists at the Cooperative Research Center for Antarctic and Southern Ocean Studies in Hobart, Tasmania compared temperatures in 1989 and 1990 with measurements taken 22 years earlier between Australia and New Zealand. They found "warming throughout most of the water column," with the largest increase of more than 0.4_C at a depth of about 3,000 decibars. In another study, these same scientists measured a comparable increase in southwestern Pacific Ocean temperatures. Tim Thwaites, "Are the Antipodes in Hot water?," *New Scientist* (November 12, 1994): 21. Bindoff reported that "On the basis of measurements made 22 years apart of full-depth temperature sections in the Pacific Ocean between Australia and New Zealand, we show here that there has been a depth-averaged warming of 0.04_C and 0.03_C at 43_S and 28_S, respectively, throughout most of the water column below the mixed layer. The sea-level rise caused by expansion between a depth of 300 m and the ocean floor is 2–3 cm, consistent with the observed rate of global sea-level rise 2 . In the main thermocline there is a coherent cooling and freshening on density surfaces, consistent with surface warming in the Southern Ocean where these waters originate. Similar observations in the North Atlantic show comparable changes in the thermal structure and water-mass volumes...." Nathaniel L. Bindoff and John A. Church, "Warming of the water column in the southwest Pacific Ocean," *Nature*.

Temperatures can be measured not only directly, but through surrogates, such as the speed with which sound is transmitted. In April 1994 scientists with the Transarctic Acoustic Propagation Experiment blasted 13 low-frequency sound pulses from Spitsbergen, Norway to receivers about 900 and 1600 kilometers away (600 and 1050 miles) at Camps Narwhal and Simi. Because the pulses, which travel faster in warm water, arrived an average of two seconds before they would have had temperature measurements taken a decade earlier by submarines remained unchanged, researchers concluded that the Arctic Ocean had warmed by 0.5_C at depths between 100 and 500 meters. Measurements taken five months later by a combined U.S.-Canadian icebreaker expedition found a one-degree increase. Five months after that, scientists at the Scripps Institute of Oceanography in La Jolla, California sent a single blast racing 6,500 miles across the Pacific Ocean as a test of their sound propagation system. It revealed a 0.5°C increase between California and New Zealand. Personal communication July 9, 1996 and "Listen Up! The World's Oceans May be Starting to Warm," *Science* (June 9, 1995).

Warming has also occurred in subsurface waters of the North Pole. Starting at the Bering Strait, a team of British and American scientists crossed the North Pole in a first-ever voyage by icebreaker, emerging between Spitzbergen and Greenland. They collected temperature data en route and compared it to earlier information from Russian ice stations and other voyages. Subsurface temperature had increased 1_C. A layer of water about 1,000 feet thick and starting at a depth of about 200 meters had warmed the most. "Taking a Bottom-to-Sky Slice of the Arctic Ocean," *Science*, (December 23, 1994): 1947.

7 As global temperature increases, the sea levels should do the same. This is partially due to the melting of glaciers and ice caps, but principally because warm water expands, thus increasing in volume. In some areas, sea levels have been measured since the 1850s. In a few other areas, mostly in the North Sea of Europe, measurements have been taken for more than three centuries. Based on these measurements, the Intergovernmental Panel on Climate Change (IPCC) has concluded that the global sea level has risen about 18 centimeters over the past century, which is consistent with the 10- to 20-centimeter rise predicted by computer models. *IPCC First Assessment Report*, Intergovernmental Panel on Climate Change, I-3.

8 **Reduction in Sea Ice and Polar Ice Covers**

If the Earth's temperature were increasing, areas covered with ice would begin to shrink. These areas range from glacial masses to polar ice covers. A variety of researchers throughout the world have confirmed that ice fields are shrinking and thinning.

Sea Ice

For example, researchers at the Nansen Environmental and Remote Sensing Center in Bergen, Norway, using satellite-based microwave measurements, found not only that sea ice is melting, but that the rate of loss has increased recently. Between 1978 and 1987, the annual rate of loss was 2.5 percent, but that rate of loss nearly doubled between 1987 and 1994, rising to 4.5 percent. "Arctic Sea Ice Melting 'Accelerated'," *Greenwire* (July 18, 1995) ***citing*** the Sydney *Australian*.

Ice Shelves

As ice flows down the frozen flanks of the Antarctic mountains and reaches the sea, it forms massive shelves that constitute roughly 11 percent of the continent's area. Floating in the frigid ocean exposed to both air and water, these shelves are extremely sensitive to even slight changes in temperature. "Antarctic Warmth Kills Ice Shelves," *Science News* (February 17, 1996): 108.

In the last 50 years as the Antarctic temperature has climbed 2.5°C, four Antarctic ice shelves have collapsed: The Wordie ice shelf measured 2,000 square kilometers in the 1940s, but has shrunk by two-thirds; the Prince Gustav has disappeared altogether. "Climate Change: Melting Ice Shelves Prompt Concern," *Greenwire* (March 28, 1995), based on reports from the *London Guardian*, *Newsweek* and the *London Independent*. The most dramatic of these collapses was easily that of the Larsen Ice Shelf in January 1995. As satellite imaging radar provided detailed images to the world's scientists, the Larsen shelf disintegrated over the span of roughly five days. Mark Fahestock, "An Ice Shelf Breakup," *Science*, (February 9, 1996): 775. At one point a slab of ice 48 miles by 22 miles (77 kilometers by 35 kilometers)—larger than Rhode Island—shattered free and floated away.

Reduction in Glacial Coverage

A variety of scientists throughout the world have studied glaciers for the purpose of detecting and measuring changes, if any. They have uniformly found that glaciers are shrinking and thinning.

Scientists from Monash University in Melbourne, Australia and Australian National University in Canberra have surveyed tropical Asia's only permanently ice-capped mountain, Indonesia's 16,023-foot Puncak Jaya Kesuma (Mount Jaya). Comparing aerial photographs of Mount Jaya from 1936 and maps drawn in 1962 with their own surveys in 1971, 1993 and 1994, they found that its glacial ice cover, which once covered 7.7 square miles, has shrunk to only one square mile. Helen Goss, "Meltdown Warning as Tropical Glaciers Trickle Away," *New Scientist* (June 24, 1995): 18.

Other glaciologists at the University of Colorado's Institute of Arctic and Alpine Research have collected a century of data from hundreds of glaciers across the world, and concluded that the Earth's total glacier mass has shrunk by 11 percent, while that of the European Alps has declined by one-half. A separate study at the Russian Academy of Science's Institute of Geography reached similar conclusions.

9 Bays and oceans are so complex that attributing change to any single cause is extraordinarily difficult. However, if global warming were occurring, scientists should be able to detect shifts in the ranges of plants and animals. Those preferring cold weather would be forced to move further up mountainsides and toward other colder climates. Those preferring warmer weather would expand their ranges. In several instances, researchers have indeed documented such shifts.

For example, in Monterey Bay, California, researchers compared current populations of sea life with those that had been found in the 1930s. Scientists in 1931 through 1933 had anchored brass bolts in bedrock to provide survey points for a 108-yard (98.8-meter) transect of the intertidal zone of Monterey Bay, which is the area that is periodically covered and exposed by the tide's ebb and flow. Over 60 years later, Stanford University researchers re-established the original one-yard-square plots, then examined 35 of them in detail. They identified 58,000 specimens. Of nine species that preferred warmer waters, eight had increased significantly. One of them, for example, *Serpulorbis squamigerus*, a sessile aggregating gastropod, had not been found at all in 1931 through 1933 and had been rarely encountered in a mid-1960s survey, but was "common" in 1993 through 1994. J.P. Barry, et. al., "Climate-Related, Long-Term Faunal Changes in a California Rocky Intertidal Community," *Science* (February 3, 1995): 672–75. In contrast, animals preferring colder waters declined sharply. During the same 60-year time span, average temperature at the shoreline rose by 0.75°C, while summertime highs were an average of 2.2°C hotter.

Other reports of rapid biological change perhaps related to warming come from tiny Macquarie Island, which lies at the center of the most rapid temperature increases on Earth. Isolated in the frigid waters of the southern Tasman Sea, roughly halfway between mineral-rich Tasmania and the frozen Antarctic continent, the island's air and water temperatures are climbing at roughly twice the global average. Uninhabited except for a research station and roughly 800 miles from the heart-shaped Australian state of Tasmania, Macquarie is immune from the usual woes of development and tourism. Nevertheless, its seal, penguin, bird and other populations are collapsing, a "clear signal that something big is happening in the Southern Ocean," according to one observer. Roughly 100,000 elephant seals—half the island's population of the five-ton animals—have disappeared, and the population of rock hopper birds has dwindled by the same amount. Scientists blame the declines on sea surface temperature increases, which they believe have caused a collapse in stocks of krill, tiny shrimp-like animals that form the base of the Antarctic marine food chain. "Climate Change: Macquarie's Woes Linked to Rising Temps?" *Greenwire* (January 24, 1996) citing the *Sydney Morning Herald* (January 13).

Analogous change, but at terrestrial sites, was found by researchers from the University of Vienna in Austria. During the summer of 1992, they inspected summit conditions on 26 Swiss and Austrian Alps higher than 3,000 meters and compared them to records from 90 years earlier. They found plants moving skyward as fast as 12 feet per decade, appearing in areas historically so cold and hostile that they had previously been devoid of plant life. Georg Grabherr, et. al., "Climate Effects on Mountain Plants," *Nature* (June 9, 1994) and Carol Kaesuk Yoon, "Warming Moves Plants Up Peaks, Threatening Extinction," *The New York Times* (June 21, 1994): C4.

10 For example, scientists from the International Development Research Center located in New Delhi, India found that in Rwanda average temperatures had risen about 1°C and that over that same period the incidence of malaria had jumped 250 percent nationally. Among children and those living in high altitude areas, the increase was more than five

fold, as the disease spread into areas where researchers said it previously had been rare or absent altogether. A key factor seemed to be nighttime warming, since cooler evening temperatures inhibit spread of both the *anopheles* mosquito and the plasmodium parasite that it transmits. Epidemics of malaria also occurred during the late 1980s in Botswana, Madagascar, Swaziland and Zambia, all countries with temperature and geography similar to Rwanda. Michael Loevinsohn, "Climatic Warming and Increased Malaria Incidence in Rwanda," *The Lancet* (March 19, 1994): 98–101.

In 1999, Texas health officials reported 16 Texas-acquired (as opposed to infections that originated in Central America or elsewhere, and later expressed in Texas) cases of dengue fever this year in Cameron, Hidalgo, Starr, Webb and Willacy counties. Texas Department of Health, "Texas Records Dengue Fever Death," Dec. 22, 1999, http://www.tdh.state.tx.us/news/b_new300.htm This was said to be the largest outbreak of dengue fever to strike the state in almost 20 years. Cable Network News, "Texas experiences first dengue outbreak in almost 20 years," Oct. 6, 1999, http://www.cnn.com/HEALTH/9910/06/dengue.fever/.

11 As releases to and concentrations of wastes in the atmosphere have risen, so too has the Earth's temperature, according to the World Meteorological Organization (WMO). It states that the globally averaged temperature of the air at the Earth's surface has warmed between 0.3 and 0.6°C (about 0.5 and 1°F) since the late 19th century. Nine of 11 years during the 11-year period from 1987 through 1997 were the hottest on record.

The National Academy of Sciences warned in 1986 that "We are pushing our climate and environment—the surroundings in which we live, work and play—into a region literally unexperienced during the history of homo sapiens .... We are reluctant to accept a reassuring forecast for a warmer globe because of imponderables. We know that major changes are likely to produce major unforeseen consequences—indeed the unforecasted Antarctic ozone hole may be just such an example of an unforeseen consequence of changes acting on a complex system." National Academy of Sciences *Current Issues in Atmospheric Change* (Washington, D.C., 1986).

12 One analysis on London air found the following pollutants: SO_2, CO, CH_4, C_2H_6, C_3H_8, nC_4H_{10}, iC_4H_{10}, nC_5H_{12}, if_7H_{12}, C_2H_4, C_3H_6, But-1-ene , But-2-ene , Butylene, Pent-1-ene , Pent-2-ene, 2-Metylbut-1-ene, 3-Methylbut-1-ene, 2-Metylbut-2-ene, C_2H_2, Toluene, o-Xylene, m-Xylene, p-Xylene, Ethyl-benzene, HCHO,0.65, CH_3CHO, C_2H_5CHO, nC_3H_7CHO, iC_3H_7CHO, C_4H_9CHO, Benzaldehyde, CH_3COCH_3, $CH_3COC_2H_5$, Diethylketone, Methyl-propylketone, Methyl-isopropylketone, CH_3OH. http://www.itass.dk/trozbas.htm

13 See, e.g., U.S. Environmental Protection Agency,"The Plain English Guide to the Clean Air Act," http//www.epa.gov/oar/oaqps/peg_caa11.html and "Transportation and Air Quality," http//www.epa.gov/otaq/index.htm. Re particle size: see "PM2.5," http//www.epa.gov/region4/sesd/pm25/p2.htm.

14 **http//www.arb.ca.gov/toxics/tac/factsheetdiesex.pdf**

15 re coal, "Bituminous and Subbituminous Coal Combustion," http//www.epa.gov/ttn/chief/ap42/ch01/final/c01s01.pdf; re vehicle fuels, "Fuels and Fuel Additives," http//www.epa.gov/otaq/fuels.htm.

16 This so called "thermal" NO_X is produced by a chemical sequence known as the Zeldovich Mechanism. At high temperature, both nitrogen (N_2) and oxygen (O_2) are dissociated into atoms that react: , , $N_2 + O$ « $NO + N$, , $N + O_2$ « $NO + O$, , $N + OH$ « $NO + H$, , NO is the principal reaction product. The major factors that affect thermal NO_X production are flame temperature, residence time at temperature, the degree of fuel/air mixing, and the concentrations of oxygen and nitrogen in the flame. See U.S. Department of Energy at http://www.netl.doe.gov/coal/turbines/background/noxform.html.

17 Although nitrous oxide (N_2O) also occurs naturally, most is formed when the nitrogen and oxygen in the atmosphere react with one another. N_2O is created during the manufacture and use of fertilizer, as well as the combustion of fossil fuels and, importantly, the making of nylon. In 1990, N_2O accounted for about 2.5 percent of U.S. emissions of greenhouse gases.

18 [913]
CLARKSON, T.W., MAGOS, L., & MYERS, G.J.The Toxicology of Mercury—Current exposures and clinical manifestationsNew Engl J Med 2003: 349: 1731–1737Notes different forms of mercury and routes of exposure. Methyl and ethyl mercury are described, and a new hazard is ethyl mercury as this is contained in thimerasol used as a preservative in vaccine. The US EPA has recently reduced the allowable intake of methyl mercury from 0.5 micrograms of mercury per kilogram of body weight per day, to 0.1.

Table gives different forms and clinical consequences; chelators are effective in treatment only for mercury vapor and inorganic divalent mercury, not for methyl and ethyl forms. CNS manifestations include peripheral neuropathy, and pneumonitis and proteinuria occur with mercury vapor poisoning. Methyl mercury causes paresthesia, ataxia, and visual and hearing loss. Increase in mercury in fish-eating birds documented from 1840 to 1965 based on feather analyses. 52 references.

[1073]
RENNER, R.
Mercury woes appear to grow.
Environ Sci Technol April 15, 2004: 144A

Mercury level in fetal blood is 1.7 times higher than in maternal blood; hence a maternal level of only 3.5 ppb in maternal blood would mean that the fetus' blood level exceeds 5.8 ppb which is considered to be the maximal safety level. Nearly 16 percent of U.S. women have mercury blood levels of 3.5 ppb or higher, according to data from the U.S. CDC.

19 Other heavy metals emitted from coal combustion include antimony, beryillium, chromium, cobalt, lead, managanese and nickel. Table 1.1-16, Emission Factor Equations at p. 1.1-37, "Bituminous and Subbituminous Coal Combustion," http//www.epa.gov/ttn/chief/ap42/ch01/final/c01s01.pdf.

20 Derwent, R., Collins, W., Johnson, C. and Stevenson, D. Transient Behaviour of Tropospheric Ozone Precursors in a Global 3-D CTM and Their Indirect Greenhouse Effects. 49 Climatic Change 4, pp. 463-87, June 2001.

21 U.S. Environmental Protection Agency, "Methane Sources and Emissions," http://www.epa.gov/methane/sources.html.

22 There have been several reports of elevated mid-ocean and rural area ozone levels. One of the most striking was that of a group of researchers from the Max Planck Institute, who remarked that "Remarkably and unexpectedly, however, in the subtropics, the tropics and the southern hemisphere, ozone increases since 1980 have been much larger. In some regions the ozone levels have even doubled in two decades. The area where the high ozone concentrations have been measured is mostly downwind of Africa, and the researchers have calculated that biomass burning and especially increasing energy use on this continent have contributed substantially to emissions of nitrogen oxides, thus catalyzing ozone formation. The implication is that increasing energy use worldwide causes large-scale ozone increases, thus reducing global air quality." Lelieveld, J. van Aardenne, J., Fischer, H. de Reus, M., Williams, J. and Winkler, P. Increasing Ozone over the Atlantic Ocean, Science Express, 13 May 2004

23 U.S. Environmental Protection Agency, "Source Contributions to PM-2.5 in Ambient Air," http//www.epa.gov/ttn/chief/eiip/pm25inventory/newtopmc2.pdf.

24 **Applied Biological Sciences**
Global atmospheric black carbon inferred from AERONET

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Contributed by James Hansen, April 1, 2003

AERONET, a network of well calibrated sunphotometers, provides data on aerosol optical depth and absorption optical depth at >250 sites around the world. The spectral

range of AERONET allows discrimination between constituents that absorb most strongly in the UV region, such as soil dust and organic carbon, and the more ubiquitously absorbing black carbon (BC). AERONET locations, primarily continental, are not representative of the global mean, but they can be used to calibrate global aerosol climatologies produced by tracer transport models. We find that the amount of BC in current climatologies must be increased by a factor of 2–4 to yield best agreement with AERONET, in the approximation in which BC is externally mixed with other aerosols. The inferred climate forcing by BC, regardless of whether it is internally or externally mixed, is {approx}1 W/m^2, most of which is probably anthropogenic. This positive forcing (warming) by BC must substantially counterbalance cooling by anthropogenic reflective aerosols. Thus, especially if reflective aerosols such as sulfates are reduced, it is important to reduce BC to minimize global warming.
http://www.pnas.org/cgi/content/abstract/100/11/6319

25 "The origin, fate, and health effects of combustion by-products: a research framework - Workshop Summaries " Environmental Health Perspectives, Nov, 2002.

Incomplete combustion processes can emit organic pollutants, metals, and fine particles. Combustion by-products represent global human and environmental health challenges that are relevant not only in heavily industrialized nations, but also developing nations where up to 90 percent of rural households rely on unprocessed biomass fules for cooking, warmth, and light. These issues were addressed at the Seventh International Congress on Combustion By-Products, convened 4–6 June 2001 in Research Triangle Park, North Carolina. This congress included a diverse group of multidisciplinary researchers and practitioners who discussed recent develop-merits and future goals in the control of combustion by-products and their effects of exposure on human and ecological health. Participants recommended that interdisciplinary, coordinated research efforts should be focused to capitalize on the important potential synergisms between efforts to reduce the adverse human health effects linked to exposures to combustion by-products and broader efforts to reduce greenhouse gas emissions and save energy through efficiency.

26 Hansen, J. "Global Warming in the 21st Century: An Alternative Scenario," Goddard Institute for Space Studies, http://www.giss.nasa.gov/research/features/altscenario/.

27 Without the effects of pollution, the natural visual range in the United States is roughly 75 to 150 kilometers (45 to 90 miles) in the East and 200 to 300 kilometers (120 to 180 miles) in the West. Because of air pollution, however, visibility ranges in the U.S. are substantially less than what they should be. In the East, sulfate is clearly the largest contributor to visibility impairment, ranging from an average 75–79 percent of each year's during the haziest days. In the eastern United States, reduced visibility is mainly attributable to secondarily formed sulfates. U.S. Environmental Protection Agency, *National Air Quality 2001 Status and Trends,*
http://www.epa.gov/air/aqtrnd01/visible.html.

28 Hansen, J., Nazarenko, L.; "Soot Climate Forcing via Snow and Ice Albedos," Proceedings of the National Academy of Sciences.

29 Novakov, T., Ramanathan, V., Hansen, J.E., Kirchstetter, T.W., Sato, M., Sinton, J.E., Sathaye, J.A.; Large Historical Changes of Fossil-Fuel Black Carbon Aerosols, Geophysical Research Letters, March 26, 2003 (Vol. 30 No. 6).

30 Surabi Menon, S., Hansen, J., Nazarenko, L., Luo, Y.; "Climate Effects of Black Carbon Aerosols in China and India," *Science*, Vol 297, Issue 5590, 2250–2253, 27 September 2002.

In recent decades, there has been a tendency toward increased summer floods in south China, increased drought in north China, and moderate cooling in China and India while most of the world has been warming. Using a global climate model to investigate possible aerosol contributions to these trends disclosed precipitation and temperature changes in the model that were comparable to those observed if the aerosols included a large proportion of absorbing black carbon ("soot"), similar to observed amounts. Absorbing aerosols heat the air, alter regional atmospheric stability and vertical motions, and affect the large-scale circulation and hydrologic cycle with significant regional climate effects.

31 U.S. Environmental Protection Agency, "Science Topics: Particulate Matter: Background," http://es.epa.gov/ncer/science/pm/#pm. See also D.V. Bates and Curtis Moore, *Health & Clean Air Newsletter*, "The Particulars of Air Quality," Spring, 2002, http://healthandcleanair.org/newsletters/spring2002.html.

32 Murray, C. and Lopez, A., Eds., The Global Volume of Disease, Volume I, World Health Organization, Harvard School of Public Health and the World Bank, Geneva, 1996. The World Health Organization estimates that one quarter of the world population is exposed to unhealthy concentrations of air pollutants. See "Air pollution," http://www.who.int/ceh/risks/cehair/en/print.html.

33 [266]
POPE, C.A.III., BURNETT, R.T., THUN, M.J., CALLE, E.E., KREWSKI, D., ITO, K., & THURSTON, G.D.

Lung Cancer, Cardiopulmonary mortality, and long-term exposure to fine particulate air pollution
JAMA 2002; 287; 1132-1141

American Cancer Society cohort recruited in 1982. Analysis of over 500,000 people in an average of 51 metropolitan districts. Interesting data showing reductions in PM2.5 from 1979-1983 and from 1999 to 2000, values ranging from 10 to 30 in the first period, and from 5 to 20 in the second. Nonparametric smoothed response functions shown for the three categories of diagnosis; conclude that for a 10 microgram/m3 change in PM10, all

cause mortality increased by 4%; cardiopulmonary mortality increased by 6%, and lung cancer mortality increased by 8%. 95% confidence levels of all indices of RR were above 1.0. Coarse particle fraction and TSP not consistently associated with mortality. Other pollutants considered were sulfate, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone. Numbers of metropolitan areas that could be considered varied with the different pollutants. Cox proportional hazards model with inclusion of a metropolitan-based random effects component in a two stage analysis. The continuous smoking variables included nine different indices (such as "current smokers years of smoking squared" and eight others). Controls also devised for educational level and occupational exposures. A 2 dimensional term was inserted to account for spatial trends. Higher regressions were noted in men than in women, and lower educational status was associated with higher risks. Risks in never smokers were also generally higher than in former or current smokers.

Authors conclude: "The findings of this study provide the strongest evidence to date that long-term exposure to fine particulate air pollution common to many metropolitan areas is an important risk factor for cardiopulmonary mortality".

The US EPA Draft Criteria Document (June 2002) makes these points about the new analysis: "(a); doubles the follow-up time from eight years to sixteen years, and triples the number of deaths: (b) expands the ambient air pollution data substantially, including two recent years of fine particle data, and adds data on gaseous co-pollutants: (c) improves statistical adjustment for occupational exposure; (d) incorporates data on dietary covariates believed to be important factors in mortality, including total fat consumption, and consumption of vegetables, citrus fruit, and high-fiber grains: and (e) uses recent developments in non-parametric spatial smoothing and random effects statistical models as input to the Cox Proportional hazards model."

34 The California Coalition for Clean Air reviewed air quality literature, and found that 1999 levels, the latest available, particularly for particulate matter (PM_{10}) were as follows:

Particulate Matter (PM_{10})
(based on 1999 data)

Rank	City	PM_{10} (ppb)*
1	Delhi, India	187
2	Cairo, Egypt	178
3	Calcutta, India	153
4	Tianjin, China	149
5	Chongquing, China	147
6	Lucknow, India	136
7	Kanpur, India	136
8	Shenyang, India	120
9	Zhengzhou, China	116

10	Jinan, China	112
62	Los Angeles, U.S.	38
78	Chicago, U.S.	27
88	New York, U.S.	23

Personal communication, March 28, 2005.

35 Hansen, J. and Nazarenko, L., "Soot climate forcing via snow and ice albedos," Proceedings of the National Academy of Sciences, v. 101: 423–28, Dec. 29, 2003. Plausible estimates for the effect of soot on snow and ice albedos (1.5 percent in the Arctic and 3 percent in Northern Hemisphere land areas) yield a climate forcing of +0.3 W/m^2 in the Northern Hemisphere. The "efficacy" of this forcing is ~2, i.e., for a given forcing it is twice as effective as CO_2 in altering global surface air temperature. This indirect soot forcing may have contributed to global warming of the past century, including the trend toward early springs in the Northern Hemisphere, thinning Arctic sea ice, and melting land ice and permafrost. If, as we suggest, melting ice and sea level rise define the level of dangerous anthropogenic interference with the climate system, then reducing soot emissions, thus restoring snow albedos to pristine high values, would have the double benefit of reducing global warming and raising the global temperature level at which dangerous anthropogenic interference occurs. However, soot contributions to climate change do not alter the conclusion that anthropogenic greenhouse gases have been the main cause of recent global warming and will be the predominant climate forcing in the future.

36 Conant, C., Nenes, A., Seinfeld, J.; "Black carbon radiative heating effects on cloud microphysics and implications for the aerosol indirect effect 1. Extended Köhler theory," J OF GEO RES, VOL. 107, NO. D21, 4604, Nov. 15, 2002.

Black carbon (BC) aerosol absorbs sunlight that might have otherwise been reflected to space and changes the radiative heating of the atmosphere and surface. These effects may alter the dynamical and hydrological processes governing cloud formation. A new, microphysical, effect of BC on climate is identified here, in which solar heating within BC-containing cloud condensation nuclei (CCN) slows or prevents the activation of these CCN into cloud drops. Solar-heated BC-containing droplets are elevated in temperature by fractions of a degree above the ambient, thus raising the droplet vapor pressure and inhibiting activation of the most absorptive CCN. This paper develops the theory describing the alteration of the Köhler curve (i.e., the equilibrium vapor pressure over a droplet as a function of water uptake) as a function of CCN size and BC fraction. The effect is most significant in those CCN that contain volumes of BC larger than a 500 nm diameter sphere. For an aerosol population with 10 percent BC mass fraction per particle, solar heating can cause a 10 percent reduction in the CCN concentration at 0.01 percent critical supersaturation. On the other hand, the effect of heating by BC absorption on CCN activation above ?0.1 percent critical supersaturation is negligible.

37 "Greenhouse Effect," McGraw-Hill Concise Encylopedia of Science and Technology, 2d Ed., p. 878, 1989. The U.S. Environmental Protection Agency defines the greenhouse effect as "The effect produced as greenhouse gases allow incoming solar radiation to pass

through the Earth's atmosphere, but prevent most of the outgoing infra-red radiation from the surface and lower atmosphere from escaping into outer space. This process occurs naturally and has kept the Earth's temperature about 59 degrees F warmer than it would otherwise be. Current life on Earth could not be sustained without the natural greenhouse effect."

http://oaspub.epa.gov/trs/trs_proc_qry.navigate_term?p_term_id=196&p_term_cd=TERM.

38 Chameides, W.L. and Bergin, M.; "Enhanced: Soot Takes Center Stage," *Science*, Vol 297, Issue 5590, 2214–2215, 27 September 2002.

39 Surabi Menon, S., Hansen, J , Nazarenko, L. Luo, Y.; "Climate Effects of Black Carbon Aerosols in China and India," *Science*, Vol 297, Issue 5590, 2250–2253, 27 September 2002.

In recent decades, there has been a tendency toward increased summer floods in south China, increased drought in north China, and moderate cooling in China and India while most of the world has been warming. Using a global climate model to investigate possible aerosol contributions to these trends disclosed precipitation and temperature changes in the model that were comparable to those observed if the aerosols included a large proportion of absorbing black carbon ("soot"), similar to observed amounts. Absorbing aerosols heat the air, alter regional atmospheric stability and vertical motions, and affect the large-scale circulation and hydrologic cycle with significant regional climate effects.

40 "Carbon monoxide poisoning," http://www.chclibrary.org/micromed/00041370.html.

41 [1007] LEE, B.E., HA, E.H., PARK, H.S., KIM, Y.J., HONG, Y.C., KIM, H., & LEE, J.T. Exposure to air pollution during different gestational phases contributes to risks of low birth weightHuman Reproduction 18; 638–643, 2003

Data from Korea, based on Seoul. 13,835 births between January 1996 and December 1998 analyzed, and pollution exposure calculated during each trimester and also during each month of pregnancy. Findings were that risks for low birth weight tended to increase with estimated CO exposure between months 2–5 of the pregnancy, with PM_{10} exposures in months 2 and 4, and SO_2 and NO_2 exposures between months3–5. Odds ratios declined to about 1.0 for exposures during the 8^{th} and 9^{th} month of pregnancy.

42 [845]
D'IPPOLITI, D., FORASTIERE, F., ANCONA, C., AGABITI, N.,FUSCO, D., MICHELOZZI, P., & PERUCCI, C.A.

Air pollution and myocardial infarction in Rome: a case-crossover analysis Epidemiology 2003: 14; 528–535

Data from the Lazio Hospital Information system which covers all public and private hospitals available to 96 percent of the population. Five monitoring stations near the center of the city for SO_2, NO_2, and CO; three stations monitored TSP. PM_{10} co-monitored was 0.7 to 0.8 of TSP. 8812 records of patients aged over 18 admitted between January 1995 and June 1997 with an acute MI. 506 cases were excluded because of a prior admission. 616 were excluded because they came from outside Rome; 554 others excluded because of doubt about the diagnosis. Present analysis includes 6531 cases.

Positive associations were found for NO_2, CO and TSP. Strongest was TSP and a 10 microgram/m^3 increase in TSP was associated with an OR of 1.028 using a 0 to 2 day lag. Association stronger for those over 74 years of age and during warmer weather. Also stronger in those with conduction disorders. NO_2 odds ratio almost equivalent to TSP.

43 [130]
KWON, H-J., CHO, S-H., NYBERG, F., & PERSHAGEN, G.

Effects of ambient air pollution on daily mortality in a cohort of patients with congestive heart failure
Epidemiology 2001: 12; 413–419

Comparison between the general population and a cohort of patients with congestive heart failure. These were hospital admissions with a primary discharge diagnosis of congestive heart failure from a medical insurance file in Seoul for the period 1994 to 1996. This program covers 96 percent of the population. Daily number of deaths averaged 90.4 per day, and of patients with congestive heart failure averaged 1.0 per day. 694 male and 1,113 female patients with congestive heart failure.

Pollutant data: 24 hour averages were PM_{10} mean 68.7 with 90^{th} percentile of 109.6; C0 (100 ppb) mean12.4; NO_2 ppb 24 hour mean 31.7 with 90^{th} percentile of 46.0; SO_2 ppb mean 13.4 with 90^{th} percentile of 25.1. One hour ozone in ppb as maximal hourly mean was 31.8 with 90^{th} percentile of 55.0.

Correlation coefficients showed NO_2 & PM_{10} = 0.775; CO and NO_2 0.744; and SO_2 and PM_{10} was 0.699.

Effects of pollutants were 2.5 to 4.1 times higher (depending on the pollutant) in the congestive heart failure cases than in the general population. Odds ratios for the general population were:

For 42.1 micrograms/m^3 of PM_{10} = 1.014; for 0.59 ppm of CO = 1.022; for 14.6 ppb of NO_2 = 1.021; for 9.9 ppb of SO_2 = 1.020; and for 20.5 ppb of ozone = 1.010.

The authors conclude: “The finding of a stronger association in the patients with congestive heart failure reinforces the evidence that a harmful effect of air pollution is

mediated by cardiovascular mechanisms." Odds ratios for the cases were PM_{10} =1.058; CO = 1.054; NO_2 = 1.065; SO_2 = 1.070; and O_3 = 1.034.

44 See, e.g., "OH takes a radical plunge—or not," *Environmental Science & Technology*, June 7, 2001, http://pubs.acs.org/subscribe/journals/esthag-w/2001/jun/science/rr_hydroxyl.html.

45 Sigg A. and Neftel A. Evidence for a 50 percent increase in H_2O_2 over the past 200 years from a Greenland ice core. *Nature* 351, 557–559 (1991). Also, Anklin M. and Bales R. C. Recent increases in H_2O_2 concentrations at Summit, Greenland, . *J. Geophys. Res.* 102, 19099–19104 (1997).

46 Thompson A. M. The oxidizing capacity of the Earth's atmosphere: probable past and future changes. *Science* 256:1157–1165 (1992).

47 Prinn, R.G. et. al., "Atmospheric Trends and Lifetime of CH_3CCL_3 and Global OH Concentrations," *Science* 269:187–192 (1995).

48 University of California at Sand Diego, "Keeling Curve," http://earthguide.ucsd.edu/globalchange/keeling_curve/01.html

49 University of California at Sand Diego, "Keeling Curve," http://earthguide.ucsd.edu/globalchange/keeling_curve/01.html

The current CO2 concentration of 374.9 ppm is the average of the 2003 annual values at Barrow, Alaska; Mauna Loa, Hawaii, American Samoa, and the South Pole (one high-latitude and one low-latitude station from each hemisphere). For records back to the late 1950s, see C.D. Keeling and T. P. Whorf http://cdiac.ornl.gov/trends/co2/sio-keel.htm. Ice-core records provide records of earlier concentrations. For concentrations back to about 1775, see A. Neftel et al., http://cdiac.ornl.gov/trends/co2/siple.htm; for concentrations back to about 1000 A.D., see D.M. Etheridge et al., http://cdiac.ornl.gov/trends/co2/lawdome.html; and, for over 400,000 years of ice-core record from Vostok, see J.M. Barnola et al., http://cdiac.ornl.gov/trends/co2/vostok.htm All these data are available from Blasing, T. and Jones, S. Current Greenhouse Gas Concentrations, Carbon Dioxide Information Analysis Center, http://cdiac.esd.ornl.gov/pns/current_ghg.html.]

50 Global surface temperatures have increased about 0.6°C (plus or minus 0.2°C) since the late-19th century, and about 0.4°F (0.2 to 0.3°C) over the past 25 years (the period with the most credible data), http://www.ncdc.noaa.gov/oa/climate/globalwarming.html#Q3

51 GIAN-RETO WALTHER, G.R., POST, E, CONVEY, P, MENZEL, A., PARMESAN, C., BEEBEE, T.J.C., FROMENTIN, J.M., HOEGH-GULDBER, O.& BAIRLEIN, F.; "Ecological responses to recent climate change," *Nature* 416, 389–395 (28 March 2002).

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HALES, S., SALMOND, C., TOWN, G.I., KJELLSTROM, T., & WOODWARD, A.
Daily mortality in relation to weather and air pollution in Christchurch, New Zealand
Australian and New Zealand Journal of Public Health 2000; 24; 89-91
Data from June 1988 to December 1993. Poisson regression models controlling for season using a parametric method. Above the third quartile (20.5 ^{o}C) of maximum temperature, an increase of 1 ^{o}C was associated with a 1% increase in all cause mortality and a 3% increase in respiratory mortality. An increase in PM_{10} lagged one day of 10 micrograms/m^3 was associated with a 1% increase in all cause mortality and a 4% increase in respiratory mortality. No evidence of interaction between the effects of temperature and particulate pollution. Mean of 7.2 deaths per day. PM_{10} values were 28 as daily average; and 71 micrograms/m^3 as a mean hourly maximum value. NO2 was 38 ppb as a mean daily average with a maximal value of 450 ppb.

53 [1150]
EL-ZEIN, A., TEWTEL-SALEM, M., & NEHME, G.
A time-series analysis of mortality and air temperature in Greater Beirut
Sci Total Environment 330 (2004); 71-80
Data show a cut off temperature (minimum mortality) of 27.5^{o}C found, with a 12.3% increase per 1^{o}C rise above this and a 2.9% decrease below it. No account taken of effect of air pollutants.

54 [839]
KOKEN, P.J.M., PIVER, W.T., YE, F., ELIXHAUSER, A., OLSEN, L.M., & PORTIER, C.J.
Temperature, Air Pollution, and Hospitalization for cardiovascular diseases among elderly people in Denver
Environmental Health Perspectives 111, 2003; 1312-1317
Daily measurements of pollutants in July and August in 1993 to 1997 in Denver compared to daily hospital admissions for people over 65 with cardiovascular diagnoses. Lag times of 0-4 days and single pollutant models used. Results indicate that O_3 is associated with an increased risk of hospitalization for acute myocardial infarction, atherosclerosis and pulmonary heart disease; SO_2 is related to increased hospital stays for cardiac dysrhythmias; and CO is significantly associated with congestive heart failure. No associations with PM_{10} or NO_2 (measured only at one site however). Higher temperatures associated with increased risks for acute myocardial infarction and congestive heart failure. Mean NO_2 was 32.7 ppb; SO_2 was 5.7 ppb: O_3 was 25.0 ppb; and CO was 0.9 ppm. Tmax was 87.4^{o}F.

55 TAGLIABUE, JOHN, “Scorching Heat Around Europe Causes Deaths and Droughts, p.A5, *The New York Times* July 19, 2005

56 The Pollution Related Health Damage Compensation Law of 1973 was enacted in 1973 (after emergency legislation in 1969). It adopted the "polluter pays" principle, levying the cost of compensating victims on polluters themselves, thereby encouraging

abatement. The Law provided for compensation in essentially two areas-1) Class 1--non-specified respiratory diseases linked to air pollution, and 2) Class 2--specified diseases linked to the emission of certain toxic waste materials which include diseases such as Minamata disease (mercury poisoning), Itai Itai disease (cadmium), and arsenic poisoning. As originally drafted, the Law provided for the designation of areas of high pollution levels, the designation of pollution-related diseases, and the designation of patients suffering from these pollution-related diseases.

Patients recognized as suffering from pollution-related diseases were awarded compensation for medical care and rehabilitation. If the patient died or his or her survivors applied within specified time limits, compensation included survivor benefits and funeral expenses. Recognized patients also receive disability payments to an amount equivalent to 80 percent of their average monthly wages, when employed. The Law did not provide payment for property damage or pain and suffering.

In 1987 the law was revised, effectively eliminating the enrollment of future victims, while allowing the approximately 98,080 formerly recognized patients to continue receiving benefits.

57 Jaeger MJ, Tribble D, Wittig JH. Effect of 0.5 ppm sulfur dioxide on the respiratory function of normal and asthmatic subjects. *Lung* 1979; 156:119–27.

58 Koenig JQ, Pierson WE, Frank NR. Acute effects of inhaled SO_2 plus NaCl droplet aerosol on pulmonary function in asthmatic adolescents. *Environ Res* 1980; 22:145–53.

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60 Sheppard D, Saisho A, Nadel JA, Boushey HA. Exercise increases sulfur dioxide-induced bronchoconstriction in asthmatic subjects. *Am Rev Respir Dis* 1981; 123:486–91.

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62 Jaeger MJ, Tribble D, Wittig JH. Effect of 0.5 ppm sulfur dioxide on the respiratory function of normal and asthmatic subjects. *Lung* 1979; 156:119–27.

63 Michael Weisskopf, "Legal Pollution That Makes Students Sick; Sulfur Dioxide Standards Don't Protect the Particularly Sensitive," *The Washington Post*, p. A1, June 6, 1989.

64 Gardner DE. Oxidant-induced enhanced sensitivity to infection in animal models and their extrapolations to man. *J Toxicol Environ Health* 1984; 13:423–39.

65 Gardner De, Miller FJ, Blommer EJ, Coffin DL. Influence of exposure mode on the toxicity of NO_2. *Environ Health Perspect* 1979; 30:23–29.

66 Rose RM, Fuglestad JM, Skornik WA, Hammer SM, Wolfthal SF, Beck BD, Brian JD. The pathophysiology of enhanced susceptibility to murine cytomegalovirus respiratory infection during short-term exposure to 5 ppm nitrogen dioxide. *Am Rev Respir Dis* 1988; 137:912–17.

67 Evans MJ, Johnson LV, Stephens RJ, Freeman G. Renewal of the terminal bronchiolar epithelium in the rat following exposure to NO_2 or O_3. *Lab Invest* 1976; 35:246–57.

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69 Hasselblad V, Kotchmar DJ, Eddy DM. Synthesis of environmental evidence: nitrogen dioxide epidemiology studies. *J Air Waste Management Assoc* 1992; 42:662–71.

70 Office of Technology Assessment, U.S. Congress, *Acid Rain and Transported Pollutants: Implications for Public Policy*, U.S. Government Printing Office at 274 (1984).

71 [268]
LEVY, J.I., SPENGLER, J.D., HLINKA, D., SULLIVAN, D., & MOON, D.

Using CALPUFF to evaluate the impacts of power plant emissions in Illinois: model sensitivity and implicationsAtmospheric Environment 36 (2002) 1063–1075 Nine power plants in Illinois studied using the CALPUFF model and meteorological data from NOAA's Rapid Update cycle model. Population-weighted annual average concentration increments associated with current emissions were 0.04 micrograms/m^3 of primary $PM_{2.5}$, 0.13 micrograms/m^3 of secondary sulfate particles, and 0.10 micrograms/m^3 of secondary nitrate particles. Plots of calculated impacts plotted against distances from the source. Maximum increment of 0.6 micrograms/m^3 close to the facilities. Attached note (from the authors) gives basis of calculating avoided health impacts per year if lower target emission levels were reached:

Mortality 190: Emergency room visits 2,532; Asthma attacks 13,290;
Restricted activity days 168,900

Each of these is broken down by county. Table of estimated emission rates for each of the nine plants. Forty percent of the primary $PM^{2.5}$ total exposure is located within 50 Km of the power plants. Population at risk is 18 million age 30 or older.

Author's note:"Pre-1980 coal-fired power plants currently contribute about half of the electricity generation in the U.S. and are responsible for 97 percent of power plant SO_2, and 85 percent of power plant NO_2 emissions"

The association between sulfate air pollution and mortality at the county scale: an exploration of the impact of scale on a long-term exposure study.

Willis A, Jerrett M, Burnett RT, Krewski D.
Department of Geography and Environmental Studies, Carleton University, Ottawa, Ontario, Canada. awillis@mail.health.uottawa.ca

The American Cancer Society (ACS) Study and its reanalysis are built upon in order to examine the impact of scale on the observed relationship between sulfates and mortality. The limitations of the original ACS Study (Pope et al., 1995) and the reanalysis of this study (Krewski et al., 2000) are discussed; while the latter dealt with some issues in using ecological data, it did not address scale. Next, the article outlines the county-scale study, the methods used to aggregate data, and the two-stage analysis used to derive relative risk (RR). Finally, the results of working at the county scale are compared with those obtained by the reanalysis team using larger metropolitan areas. Less than half of the cohort used in the metropolitan study were used at the county scale because of the limited availability of sulfate monitors and because five-digit ZIP codes more accurately assigned individuals to geographical areas. Therefore, the county data should be considered as new and not as a reorganization of the original data set. The reanalysis and the county studies should be considered as two separate studies that took different scales as their basic organizing principle. The RR of all-cause mortality from sulfate exposure at the county scale was 1.50 (1.30, 1.73) compared with 1.25 (1.13, 1.37) at the metropolitan scale; for cardiopulmonary mortality, the RR was 1.75 (1.48, 2.08) at the county scale compared with 1.29 (1.15, 1.46) at the metropolitan scale. Because lung cancer mortality was low in some counties, the two-stage random effects model became unstable. At the county scale, the RR from sulfates was more robust to the inclusion of ecologic covariates. Other place-specific ecologic covariates were either insignificant or barely significant (with a lower 95 percent confidence limit near 0.99 or 1.00) when included in the two-stage regression model for all-cause mortality with sulfates. Moreover, no ecologic covariate changed the RR of all-cause mortality from sulfates by 25 percent or more. Both population change and unemployment rate affected the RR for cardiopulmonary mortality from sulfate exposure by 25 percent or more in the county-scale analysis. However, when these two variables were entered into a multiple covariate analysis, the RR from sulfates decreased but remained strongly significant. Sulfur dioxide was not an important covariate at the county scale. Thus, at the county scale, long-term exposure to sulfates appears to be more strongly associated with increased risk of all-cause and cardiopulmonary mortality than previously indicated by the ACS study and its reanalysis.

72 Although there have been significant reductions in emissions of sulfur dioxide in the United States in part because of the Clean Air Act Amendments of 1990, 41 percent of lakes in the Adirondacks and nearly 15 percent of New England lakes remain acidic, and their recovery is hampered by the acidic anions slowly leaching from the soils. Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic Deposition in the Northeastern United States: sources and inputs, ecosystem effects, and management strategies.

BioScience 51(3):180–198.

73 Although there have been significant reductions in emissions of sulfur dioxide in the United States in part because of the Clean Air Act Amendments of 1990, 41 percent of lakes in the Adirondacks and nearly 15 percent of New England lakes remain acidic, and their recovery is hampered by the acidic anions slowly leaching from the soils. Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic Deposition in the Northeastern United States: sources and inputs, ecosystem effects, and management strategies. BioScience 51(3):180–198.

74 Pennsylvania State University, *The Effects of Acidic Deposition on Pennsylvania's Forests* (1999); University of North Carolina at Chapel Hill, "Effects of Air Pollution in Southern Appalachians," http://www.unc.edu/~dcrawfor/effectap.htm.

75 U.S. Environmental Protection Agency, *Acid Rain Program 2001 Progress Report*, p. 37, http://www.epa.gov/airmarkets/cmprpt/arp01/2001report.pdf.

76 The U.S. Environmental Protection Agency has reported a 24 percent decrease in emissions of sulfur dioxide from 1992 to 2001. Yet these reductions are not being manifested by visibility improvements. In the West, visibility impairment for the worst days remained relatively unchanged over the 1990s, with the mean visual range for 1999 of 80 kilometers nearly the same as the 1990 level of 86 kilometers. According to EPA, over the 1992–1998 period, the magnitude of aerosol extinction due to sulfates, increased, most notably between 1997 and 1998. "This corresponds," EPA noted in its 1998 *National Air Quality and Emissions Trends Report*, to an "increase in sulfate aerosols and summertime increase in regional SO_2 emissions." U.S. Environmental Protection Agency, *National Air Quality 2001 Status and Trends,* http://www.epa.gov/air/aqtrnd01/visible.html. EPA concluded in its 1998 report that "overall, essentially no change in visibility is noted between 1989 and 1998," adding that "a 4-percent *degradation* has occurred since 1992." (emphasis added) U.S. Environmental Protection Agency, *National Air Quality 2001 Status and Trends,* Chart "Visibility Trends for Eastern U.S. Class I Areas, 1992–1999," http://www.epa.gov/air/aqtrnd01/visible.html.

77 Intergovernmental Panel on Climate Change, "IPCC Special Report on Emissions Scenarios" http://www.grida.no/climate/ipcc/emission/125.htm

78 Indeed, ozone is such an effective sterilant that it was one of several decontamination alternatives examined by the Department of Homeland Security in the wake of the 9/11 and anthrax terrorist attacks of 2002. Compilation of Available Data on Building Decontamination Alternatives, http://www.epa.gov/nhsrc/pubs/reportBuildDecon052705.pdf.

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McCONNELL, R., BERHANE, K., GILLILAND, F., LONDON, S.J., ISLAM, T., GAUDERMAN, W.J., AVOL, E., MARGOLIS, H.G., & PETERS, J.M.

Asthma in exercising children exposed to ozone: a cohort study
Lancet 2002; 359; 386–391

From the Southern California Children's Study. Relevant numbers;
5762 children completed baseline questionnaires;
479 excluded because they were not at school when the questionnaire was administered;
883 excluded for a history of asthma;
312 excluded because of missing answers to "wheezing" questions;
26 excluded for chest illnesses such as cystic fibrosis:
527 excluded because they had less than one year of follow-up;

This left 3535 children with no initial history of asthma; 2752 of these had no history of wheezing; 1934 played sports; 273 played three or more team sports;

There were 46 low pollution communities (O_3 daytime mean 40.0 ppb); and 46 high pollution communities (O_3 mean 59.6 ppb). PM_{10} twice as high in high ozone communities (43.3 vs 21.6) and $PM_{2.5}$ three times higher (21.4 vs 7.6). NO_2 three times

higher in high ozone communities (29.2 vs 10.8 ppb).

It was shown that development of asthma prospectively was three times higher in children participating in more than three sports in high ozone communities, compared to children who did no sports in both communities or did fewer than three sports in high ozone communities. No differences in development of asthma if other pollutants were studied. Excellent discussion; 32 references. Convincing argument as to why standard cross-sectional comparisons might show no differences in prevalence of asthma.

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88 Kinney and Ozkaynak. Associations Between Ozone and Daily Mortality in Los Angeles and New York City. *Am Rev. Respir. Dis.*, 145(4:2):A95, 1992.

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Significant associations across lag times and age groups found between spring and summer O_3 levels and respiratory mortality. 4.30 percent increase per 10 microgram/m^3 of the 4 daily mean O_3 level for respiratory causes, and 2.42 percent increase for total mortality. PM_{10} also consistently associated with respiratory mortality (3.96 percent increase per 10 microgram/m^3 across lag times and age groups). All models were "adjusted" for temperature, but no specific association (or lack of it) between temperature and mortality is mentioned.

90 Kinney, et al. A Critical Evaluation of Acute Ozone Epidemiology Results. *Arch. Env. Health* 43, 168–73, 1988.

91 U.S. Environmental Protection Agency, *Air Quality Criteria for Ozone and Related Photochemical Oxidants (First External Review Draft, Volume III*, Jan. 2005, see especially pp. 9-1 to 9-396.

92 U.S. Environmental Protection Agency, *Air Quality Criteria for Ozone and Related Photochemical Oxidants (First External Review Draft, Volume III*, Jan. 2005, p. 9-327 See also Nolle, M., Ellul, R. & Güsten, H. Constant Flux-Layer Approach for Correction of Historical Schönbein-Type Ozone Measurements of the Gozo Series from 1884–1900—Comparison with Present Day Ozone Records on Gozo, http://64.233.161.104/search?q=cache:an8ZDpkjjiEJ:www.um.edu.mt/pub/Garmischabstract.pdf+volz+ozone+kley&hl=en, concluding that ozone levels on the remote Mediterranean island of Gozo have increased five-fold in the past century. See also Volz, A., and D. Kley. 1988. Evaluation of the Montsouris Series of Ozone Measurements

Made in the Nineteenth Century. Nature 332:240–242., concluding that at the Montsouris Observatory close to Paris mean ozone concentration varied between 5 and 15 ppb 100 years ago.

93 A. Volz and D. Kley, "Evaluation of the Montsouris Series of Measurements Made in the Nineteenth Century," *Nature* 332 (1988): 240–43. See also S.A. Penkett, "Atmospheric Chemistry: Increased Tropospheric Ozone," *Nature* 332 (1988): 204.