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I am a public health physician, a graduate of Harvard Medical School and the former Dean of the School of Public Health at the University at Albany. My research interests are the study of the impact of environmental exposures on human health, with a special focus on adverse effects on children. I have over 340 publications in peer-reviewed scientific literature, including a number of studies of the effects of air pollution and mercury on human health. I serve as an advisor to the World Health Organization and the National Institute of Environmental Health Sciences, and am a member of the Science Advisory Board of the International Joint Commission, the body that advises the governments of the US and Canada on issues around the boundary waters such as the Great Lakes. In this capacity I chair a workgroup dealing with issues related to concerns over consumption of fish, where mercury is one subject of study. I am the former President and current Treasurer of the Pacific Basin Consortium for Health and Environment, an international organization that coordinates activities of all of the countries in the Pacific Basin around issues related to air pollution, hazardous wastes and human health consequences of exposure to contaminants.

Power plants provide electricity to satisfy a variety of societal needs. Some power plants, such as hydroelectric, nuclear, wind, and solar, provide energy without air pollution, but fossil fuel-fired power plants are the major source of electrical power in most countries. Unfortunately, fossil fuel-fired power plants emit millions of tons of air pollutants each year (Environmental Integrity Project, 2007; Krewitt et al., 1998). In addition to formation and release of CO_2, which is a major concern with regard to climate change, fuel-fired power plants release sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), acid gases and volatile organic compounds. Coal-fired power plants are the largest single source of release of mercury. While these air pollutants are also released by other sources of fossil fuel combustion, such as traffic, fossil fuel power plants are localized sources of elevated air pollution.

Hazardous air pollutants pose significant danger to human health of persons of all ages, but especially for the very young (Hertz-Picciotto et al., 2007) and older individuals with ill health (Zanobetti and Schwartz, 2005). The major components of hazardous air pollution include particulates (which often contain PAHs and metals), SO_x, NO_x and ozone, which is formed by the interactions between NO_x, sunlight and oxygen. Acid gases are also released, which include HCl, H_2S and HF. Sulfur dioxide comes primarily from fossil fuel burning, electrical power plants and industrial facilities, and combines with water to make sulfuric acid. As such, it is a major contributor to acid rain. When SO_2 is inhaled sulfuric acid forms in the lung. This is a very damaging substance, and it degrades lung tissue, causing serious lung damage, which can be irreversible with chronic

inhalation. Nitrogen oxides are also released from industries and power plants, and when inhaled form nitric acid, which also directly damages the lung. While each of these pollutants alone have adverse health effects, in the real world people are exposed to all of them simultaneously. A major problem arises when individuals are exposed to chemical mixtures. While standards are usually set based on single chemicals or gases, exposure is actually to multiple chemicals or gases. The adverse health effects of the individual components may be additive, or, even more dangerously, may be more than additive; meaning that the sum can be greater than the parts (Carpenter et al., 1998; 2002). Air pollution is never of a single pollutant, and usually particulates, NO_x, SO_x, ozone, CO and CO_2 are all components, as well as volatile organic compounds (VOCs) such as benzene and 1,3-butadiene and acid gases. Thus, the net hazard is much greater than just that from a single component (Lippmann and Schlesinger, 2000). Of particular concern is risk of cancer, respiratory diseases including both infectious disease and asthma, cardiovascular disease and death from any cause.

Coal-fired power plants produce more hazardous air pollution in the United States than any other industrial pollution sources. The Clean Air Act requires the control of hazardous air pollutants from coal-fired power plants, but absent these new rules, no national standards exist to limit these pollutants from these plants. In the US, there are more than 400 coal-fired power plants located in 46 states across the country release in excess of 386,000 tons of hazardous air pollutants into the atmosphere each year.

Hazardous air pollutants are toxic emissions that are known or suspected to cause cancer or other serious health effects, such as reproductive problems or birth defects. People most at risk include: infants, children and teenagers; older adults; pregnant women; people with asthma and other lung diseases; people with cardiovascular disease; diabetics; people with low incomes; and healthy adults who work or exercise outdoors. Based on data from the American Cancer Society, the Clean Air Task Force has estimated that over 13,000 lives would be saved if the Transport Rule were implemented, and that the adverse health impacts attributable to coal-fired power plants alone is in excess of $100 billion dollars.

The diseases of concern from air pollutants are as follows:

Lung Cancer: Particulates contain several kinds of cancer-causing substances, primarily PAHs, metals such as arsenic and chromium and volatile organic compounds. These substances accumulate over time and increase risk of development of lung cancer (Sax et al., 2006). Pope et al., (2002) reported that each 10 $\mu g/m^3$ elevation in fine particulate levels resulted in an 8% increased risk of development of lung cancer mortality. Reynolds et al. (2003) reported on rates of childhood cancer in relation to concentrations of 25 hazardous air pollutants, including benzene, 1,3-butadiene, chloroform, ethylene dibromide and dichloride, vinyl chloride and trichloroethylene, and found that a significant association between concentrations of these substances and rates of leukemia in children [risk ratio (RR) = 1.21, 95% CI = 1.03-1.42].

Sudden death from cardiovascular and respiratory disease: Individuals who already suffer from ill cardiac or respiratory health have a significantly increased risk of

dying on days of high air pollution. Samet et al. (2000) investigated fine particulate air pollution and mortality in 20 US cities and found an increased risk of death from all causes of 0.51% for each increase in PM_{10} of 10 $\mu g/m^3$, and an increase of 0.68% for cardiovascular and respiratory mortality. Pope et al. (2002) found that a 10 $\mu g/m^3$ elevation in fine particulate air pollution was associated with a 4% and 6% increase of all causes and cardiopulmonary mortality, respectively. Zanobetti and Schwartz (2005) reported that for every increase of 10 $\mu g/m^3$ in PM_{10} there was a 0.64% increase in risk of hospitalization for myocardial infarction. Ito et al. (2011) found that hospitalization for cardiovascular disease exhibited strong seasonal trends and day of the week patterns that correlated with levels of fine particulates in air. Wang et al. (2009) reported that an increase of 4.7% in cardio-respiratory mortality with every 1 ppb increase in annual average concentration of SO_2. Hermann et al. (2004) predicted that if 29 proposed fossil-fuel power plants in Virginia were operated for 6 years, $PM_{2.5}$ in 272 counties would increase and 104 additional premature deaths would occur.

Chronic obstructive pulmonary disease (COPD): Air pollutants lead to an increased frequency of hospitalization for COPD, and may contribute as a cause of this disease (Moolgavkar, 2000; Chen et al., 2004). Studies indicate that SO_2 and NO_2 are particularly important is causing this effect.

Respiratory infections: Research studies show an increased risk of hospitalization of children for pneumonia, bronchitis and respiratory distress during periods of elevated air pollution (Romieu et al., 2002; Hertz-Picciotto et al., 2007; Ostro et al., 2009; Sheffield et al., 2011). The latter study calculated that if the United States were to reduce levels of fine particulate matter to 7% below the current annual standard, the nation would save $15 million dollars annually in reduced health care costs. Chauhan and Johnston (2003) have presented evidence that air pollution in general, but NO_2 in particular, increases the risk of infectious respiratory illnesses. Dales et al. (2006) found a 1.66% increase in neonatal hospitalization for respiratory diseases of Canadian neonates in relation to inter-quartile concentrations of NO_2.

Respiratory allergies: Parker et al. (2009) report an increase in frequency of respiratory allergies and hay fever, especially in children, in relation to levels of ozone and particulate matter (Parker et al., 2009).

Asthma: Air pollutants cause an increased frequency of asthma attacks in both children (Schildcrout et al., 2006; Smargiassi et al., 2009) and adults (Delfino, 2002), particularly in relation to elevated levels of SO_x and NO_x. Samoli et al. (2011) reported that a 10 $\mu g/m^3$ increase in SO_2 was associated with a 5.98% increase in the number of pediatric asthma hospitalizations. Johns et al. (2010) exposed asthmatics to SO_2 for 5-10 min periods, and observed consistent evidence of an increase in broncho-constrictive responses with increasing exposure to concentrations between 0.2 and 1.0 ppm. Andersson et al. (2006) determined the incidence of adult asthma among persons exposed to SO_2, and found a highly significant elevation in asthma in exposed, as compared to unexposed persons [hazard ratio (HR) = 4.0, 95% CI = 2.1-7.7]. Liu et al. (2009) studied pulmonary function in children in Windsor, Ontario in relation to levels of $PM_{2.5}$, SO_2, and NO_2, and found that elevated pollution with all three increased the airway oxidative stress and decreased small airway function in asthmatic children.

Reduced neurologic development of children: Recent studies have found that elevated levels of air pollutants are associated with reduced motor and language development of children (Tang et al., 2008; Perera et al., 2008).

Low birth weight infants and prematurity: Chronic elevation in levels of air pollutants increases the risk of infants being born prematurely and having low birth weights (Bobak, 2000). Sram et al. (2005) and Ritz and Wilhelm (2008) have reviewed evidence for relations between ambient air pollution and birth outcomes, and find that all criteria pollutants are linked to adverse birth outcomes. They found evidence for reduced birth weight with increased air pollution, and evidence for preterm birth and intrauterine growth retardation with increasing air pollution. They report evidence for a relationship with birth defects, but this evidence is not strong.

My colleagues and I have recently completed a study of the effects residence near to fuel-fired power plants in New York and rates of hospitalization for respiratory diseases. There is increasing evidence that environmental exposures increase the risk of human disease, and these exposures come from multiple sources including air pollutants coming from fossil fuel combustion whether in power plants or vehicles. While many of the important sources of air pollutants are mobile, power plants, because they are stationary, constitute a localized source of air toxics, and as such allow one to ask the question of whether individuals living near to these power plants experience greater exposure and more disease as a result. The goal of this study was to examine rates of hospitalization for asthma and respiratory infections among individuals who live near to fuel power plants. The manuscript was submitted to a scientific journal less than two weeks, and has not yet been accepted for publication.

We used the New York Statewide Planning and Research Cooperative System (SPARCS) to obtain data on hospital discharges for the years 1993–2008. SPARCS is an administrative database maintained by the New York State Department of Health (NYSDOH). Every state-regulated hospital (except federal hospitals) must report to NYSDOH the primary diagnosis and up to 14 other diagnoses of each inpatient upon discharge, based on the International Classification of Disease, 9th Revision (ICD-9). In this study, we selected hospital discharge data that had diagnosis of (1) asthma (ICD-9: 493), (2) acute respiratory infections (ARI) (ICD-9: 460–466) and/or (3) chronic obstructive pulmonary disease (COPD) (ICD-9: 490–492 and 494–496) and included both primary and secondary diagnoses. We used this data for the years 1993-2008.

Exposure was defined as a patient's residence in a zip code that contained at least one power plant using fuel combustion as an energy source. We obtained the list of existing power plants and electric generators in New York State for the years 1990–2008 from the website of the U.S. Energy Information Administration (EIA) (US EIA, 2010). We have information about location, energy source and operating period for each generator. Fossil fuel-fired power plants used coal, oil, natural gas, landfill gas and/or solid waste. Using this information, we have created a database that identifies the zip codes that contained fuel-fired generators in all of New York State except for NYC.

We found that after adjustment for age, gender, race, median household income (MHI) and rural/urban residence, there was a significant 11%, 15% and 17% elevation in

rates of hospitalization for asthma, respiratory infections and COPD, respectively, among individuals age > 10 years living in a zip code containing a fuel-fired power plant as compared to one that had no power plant. Our results are consistent with the conclusion that exposure to air pollution from fossil fuel-fired power plants increases the risk of hospitalization for respiratory diseases

Although semi-ecologic studies such as ours must always be considered to be hypothesis generating, the congruence between these results and previous information provides additional evidence that use of the large hospitalization dataset has value in identifying patterns of disease in relation to residential exposures.

Coal-fired power plants are also the single greatest source of release of mercury. There are three major forms of mercury, metallic, inorganic and organic. Because mercury is an element, it cannot be destroyed. While there is some toxicity associated will all forms of mercury, the organic form, primarily methyl mercury, is the most dangerous. Methyl mercury is formed through the action of microorganisms in aquatic sediments. Release of mercury from power plants results in it being deposited into bodies of water, where it is then converted to methyl mercury. The major source of human exposure to methyl mercury is consumption of fish, both marine and fresh water, that accumulate and bioconcentrate methyl mercury.

Methyl mercury is an extremely dangerous substance, and of greatest concern is the fact that it is a neurotoxicant that causes significant reduction in IQ of children born to mothers with elevations concentrations (Debes et al., 2006; Bose-O'Reilly et al., 2010). The National Academy of Sciences in 2000 reviewed the evidence that mercury caused human disease, and concluded that children born to mothers who eat large amounts of fish are at greatest risk. Based on data from the National Human Monitoring project there is evidence that 8 to 10% of women of childbearing age in the US have concentrations of methyl mercury in their bodies beyond the levels that EPA considers to be "safe". Fully 87% of this mercury comes from combustion point sources, and 33% of that comes from coal-fired utilities. A recent analysis has reported that mercury released from US power plants results in $1.3 billion in lost economic productivity as a consequence of the reduction in IQ that results (Trasande et al., 2005).

While the effects of children's neurologic development is the greatest concern, mercury exposure also causes severe neurological disease in adults (Hightower and Moore, 2006) and increases the risk of cardiovascular disease (Guallar et al., 2002). My colleagues and I have recently published information to assist physicians in identifying the signs of mercury poisoning in adults (Silbernagel et al., 2011).

In summary, air pollutants coming from power plants result is significant human morbidity and mortality. This is also the case for mercury released from power plants, which contaminates fish and makes fish often unsafe to eat, especially for women and children. It is critical that every possible step be taken to reduce the release of these compounds so as to protect human health.

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