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The Harmful Effects of Coal-Generated Electricity

As industrial societies expand, our environment suffers as a consequence of growth. After recognizing that health and well-being are related to the quality of the environment, attempts are underway to apply the principles of science and engineering to provide healthful land, air and water, and to repair the damages of industrialization. Despite technical advances over the last century, as yet, there has been no significant change in our reliance on fossil fuels, in particular, coal to generate electricity. According to the U.S Department of Energy, in 2008 one third of the world's electricity was generated from coal.

Coal-fired power plants are one leading cause of air pollution. Typical US coal-powered plants produce several major pollutants, per year creating about 3.7 million tons of carbon dioxide (a primary cause of global warming), 10,000 tons of sulfur dioxide (the leading cause of acid rain), 500 tons of airborne particulates (causing bronchitis, asthma, smog, and premature death), 10,200 tons of nitrogen oxides (leading to ozone formation and respiratory illness), and 720 tons of carbon monoxide (causing heart disease.[1])

Acid Rain and Airborne Particulates:

Nearly all of the world's coal-generated electricity is produced using pulverized-coal combustion systems.[2] In pulverized-coal combustion, coal is crushed to a powder and blown into a boiler with air where it is burned to provide steam for a turbine that runs an electric generator. The gaseous products of this combustion come out of a chimney or smokestack; they include carbon dioxide, water vapor, nitrogen, nitrogen oxides, sulfur oxides, fly ash, and mercury. All of these products have harmful ecological and health consequences.

When formed in air containing sulfur oxides or nitrogen oxides, rain becomes acidic. This “acid rain” is harmful for plants, aquatic animals, and buildings.[3] Sulfur and nitrogen compounds react with water and oxygen in the atmosphere to produce acids:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Acid rain is a substantial problem in parts of Europe, China, and Russia as well as in areas downwind of these countries. China, Russia and some European countries burn high-sulfur-containing coal to generate electricity and heating in houses. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain and widespread ecological damage.[3] The contaminated rain enters surface waters of lakes and rivers that can damage the biodiversity of ecosystems. According to the U.S Environmental Protection Agency (EPA), at a pH lower than 5, fish eggs do not hatch, and at still lower pH, adult fish die. In addition, at low pH, soil microbes are unable to function. Their enzymes are denatured by the acid, and the microbes die. Soil is drastically changed when base cations such as Ca^{2+} and Mg^{2+} are leached out by acid rain. Sensitive plants, for example, the sugar maple, can die by this leaching. Acid rain has also damaged building materials and historical monuments through chemical reaction with calcium compounds in limestone, sandstone or marble to create calcium sulfate, which then flakes off.

$$CaCO_3 + H_2SO_4 \leftrightharpoons CaSO_4 + CO_2 + H_2O$$

Repair of buildings, and monuments costs billions of dollars per year.[3]

Perhaps the most important consequences of acid rain are those that affect human health. Studies from the EPA have linked gases that form acid rain to illness and premature death. These disease including: asthma, lung cancer, and Alzheimer's disease cardiovascular disease, such as vascular inflammation, and arthrosclerosis.[4]

Sulfate particles are the major cause of smog in many parts of the United States and elsewhere. Aside from visual impairment and noxious smell, smog causes respiratory illness and aggravates heart and lung diseases. Exposure to even concentrations as low as 0.5 to 5 ppm may burn the lungs and throat, and cause bronchitis.[14] Chronic low-level exposure depletes the respiratory system's ability to defend the human body against bacteria and foreign particles.[5]

Before burning, some companies separate sulfur content from coal. These pre-combustion technologies include physical washing and crushing of the coal with water, to remove about 90% of pyritic sulfur impurities. However, sulfur chemically bonded to carbon in coal cannot be removed by washing; it is primarily this chemically bonded sulfur that enters air following combustion.

Aware of these negative effects, some coal-fired power plants have installed "scrubbers" that trap sulfur emissions before they are released into air. These scrubbers turn sulfur emissions into sludge and solid waste. However, scrubber technology is expensive and it is not clear where to dispose the solid waste byproducts.[6] According to the EPA, only 30% of the solid waste is recycled into commercial building products. The other 70% of scrubber sludge and coal ash is deposited in landfills that can poison rivers and ponds, contaminating drinking water.[7] In 2006, of the 257 U.S coal-fired power plants that produce more than 2,000 GWh of power per year, 86 had sulfur dioxide emissions higher than 10 lb/MWh, compared to the average of 1 lb/MWh for coal power plants with scrubbers. These 86 plants have minimal or nonfunctional scrubbers, or perhaps none at all.[6] A major deterrent to installing scrubbers is cost for both the power companies and consumers, although they are needed to ensure that emission standards are met. Despite the billions of dollars in annual revenue of coal-based energy companies, many have failed to install scrubbers on their oldest or dirtiest coal plants. American Electric Power, Southern Company, and Duke Energy, the top three companies in terms of coal-powered energy production, collectively own 32 of the dirtiest coal-power plants.

Because scrubber technology is so expensive, an alternative is to use low-sulfur coal. Eastern states such as Ohio, Pennsylvania, and West Virginia have coal with a high sulfur content that accounts for 3 to 10 percent of coal's total weight, while coal from Western states such as Wyoming, Montana, Utah, and Colorado have sulfur contents less than 1 percent of coal's total weight. The U.S Department of Energy estimates that using low-sulfur coal can reduce up to 85% lower emissions compared to those from high-sulfur coal.[8] However, low-sulfur coal is expensive. As the demand for energy and domestic coal continues to grow, consumption of high-sulfur coal is projected to continue.[8]

Nitrogen Oxides:

In addition to sulfur oxides, nitrogen dioxide is oxidized by the hydroxyl radical (from water) in air to form nitric acid:[3]

$$NO_2 + OH^- \rightarrow HNO_3$$

When nitric acid contacts lung tissue, serious damage can result, in extreme cases leading to premature death, or to respiratory diseases such as emphysema, bronchitis and aggravated heart disease.[10] It is possible to convert nitrogen oxides from smokestacks into harmless nitrogen and water, using a Selective Catalytic Reduction Unit, or SCR. A reducing agent, normally urea or ammonia, is injected into the smokestack, passing over a catalyst mixture of vanadium (the active catalyst) and titanium (used to disperse and support the vanadium) to initiate the following chemical reaction:[15]

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

Using ammonia, Nitrogen oxide emissions are reduced by 80 to 90%. However, using an SCR for nitrogen oxide control in power plants generates ammonium sulfates that are undesirable because they catalyze formation of SO_3 from SO_2 and O_2 leading to acid rain. Un-reacted ammonia forms NH3 slip that can cause plugging and corrosion of equipment and catalyst beds.[10]

This technology, although highly effective, is expensive, costing power companies approximately $2500 per ton of NOx removed. However, these costs are highly dependent on plant capacity, degree of NOx removal and initial NOx concentration. Longer catalyst life and/or reduced catalyst prices would help to reduce costs.[10]

Power companies claim that being environmentally responsible by using existing technology and disposing hazardous waste material is too costly. Consumers want cheap electricity and expect power companies to pay for green-energy practices instead of increasing utility bills. Ultimately, the cost of reducing smokestack emissions must be a shared nationwide by employees, taxpayers, investors and customers. It has been estimated that it will cost $11.5 billion to clean up old coal-powered plants.[11] Simultaneously, there must be legislation enforced to hold power companies accountable for following federal and state guidelines. Twenty-three states do not regulate what industries do with coal ash, and no federal standards currently exist. This situation is unacceptable for human safety. The thirty-year-old Clean Air Act needs to be revised, because some reports say as many as 30,000 people die every year from pollution in the United States, including 2,800 from pollution-based lung cancer.[12] According to Conrad Schneider, advocacy director of the Boston-Based Clean-Air Task Force, *"More people die as a result of pollution from these plants every year than from drunk driving or homicide, societal woes that everyone agrees are top priorities*."[11] All of these deaths could have been prevented if the US had stricter regulations on pollution control.

There is hope. Following the December 2008 coal-ash spill in Harriman, Tennessee, the Coal Ash Reclamation and Environmental Safety Act of 2009 was introduced in the House of Representatives.[13] If passed, this legislation may provide the first action on the federal level since coal ash was designated a toxic material three decades ago. Perhaps when law finally catches up with available science and technology, significant steps will be taken towards cleaner, safer energy from coal-generated electricity plants.

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