Power Plants and Particulate Matter: Formation and Direct Emissions

Fine particles in the air have been associated with adverse health effects; hence, EPA has established regulations to limit the amount of fine particles to which people are exposed.

The Earth's atmosphere contains particulate matter (PM) composed of many chemical compounds. These particles can originate from both natural sources (such as wind-blown dust, pollen, or from gases emitted by trees and vegetation) and human activities (for example, burning fossil fuels, garbage, or crop wastes, driving our cars; using fireplaces, cooking food, and numerous industrial activities). In 1997, the U.S. Environmental Protection Agency (EPA) established national ambient air quality standards (NAAQS) for fine particulate matter. Fine particulate matter (commonly referred to as PM2.5—that is, particles 2.5 micrometers and less in diameter, or about 20 to 40 times smaller than the width of a human hair) tends to be inhaled into the lungs more readily than relatively larger particles present in the atmosphere and is thought to be associated with adverse health effects such as respiratory diseases and certain forms of heart disease.

EPA measures atmospheric fine particle mass concentrations throughout the country to determine which regions are in compliance with the new standard and which regions fail to meet it. These regional compliance designations were finalized on December 17, 2004. In regions that do not meet the NAAQS, individual states must develop and enforce plans to control the sources of fine particulates—such as wood burning, factories, power plants, and motor vehicles—so that air quality improves to the level of the standard within a prescribed timeframe.

All coal-fired power plants use particulate matter removal equipment (such as electrostatic precipitators (ESPs) or fabric filters) to remove fly ash from boiler exhaust gases before they reach the stack.

These particulate controls are very effective, capturing more than 99% of the ash present from exhaust gases. Thus, in the vicinity of typical power plants, the ash particles that escape from the stack account for an extremely small amount of ground-level fine particulate matter in the air.

Power plants burning coal transform sulfur in the fuel to sulfur oxides (SOx). The major chemical form emitted by power plants is sulfur dioxide, or SO2. Sulfur trioxide (SO3), another form of SOx, constitutes approximately 0.5 % to 2 % of the SOx. Fossil fuel combustion also transforms nitrogen present in fuel and combustion air to nitrogen oxides: nitrogen oxide (NO) and nitrogen dioxide (NO2). NOx is primarily released as NO from the stack and converts to NO2 in the atmosphere.

Like ash emissions, power plant SO2 and NOx emissions are controlled in a variety of ways. SO2 emissions are substantially controlled by "scrubbers" or through the use of low-sulfur coal. NOx emissions are decreased via "low-NOx burners" or other furnace modifications as well as by the use of exhaust gas catalysts similar to the catalytic converters found in automobiles.

Reactions in the atmosphere convert a portion of the SO2 and NOx emissions released from the power plants to sulfate and nitrate particles, respectively. Sulfates and nitrates from all combustion sources (such as power plants, motor vehicles, industry, and airplanes) comprise varying amounts of the fine particulate mass in the United States, depending on the region and meteorological conditions. Other important components of fine particulate mass include carbon-containing compounds (such as organic matter from natural and human activities as well as the black carbonaceous component of "soot") and soil dust. The relative mix of sulfates and nitrates varies from urban to rural areas, with nitrates being relatively higher in urban centers (especially during the winter months) and sulfates being relatively higher in rural regions. Although it is difficult to

pinpoint the fraction of sulfate and nitrate fine particulates attributable to power plant SOx and NOx emissions, power plants are potentially significant contributors, primarily to atmospheric sulfates.

One study claimed that coal-fired power plants emit up to 17 times more fine particulates than previously thought, chiefly because of SO3 emissions.

An article in *Energy Daily* (8/7/02) claimed that EPA has underestimated fine particulate emissions from coal-fired power plants, and that they may be as much as 17 times higher than previous estimates. On the basis of its higher estimate, the article claimed that power plants are responsible for a much larger share of the fine particulate matter in the air, and consequently may be contributing to adverse health effects. Specifically, it cited SO_3 emissions as being underreported, and noted that such emissions are not regulated by current limits on power plant emissions of solid particulate matter (that is, ash).

An Electric Power Research Institute (EPRI) analysis of SO_3 emissions and direct particulate matter (fly ash) emission rates has determined that these are quite low for most power plants. Power plant ash emissions account for much less than 1% of ambient fine particulate mass and sulfate aerosols from SO_3 emissions contribute to similarly small amounts of the total ambient fine particulate mass (somewhat higher for plants burning moderate sulfur coals and fairly low for plants burning low sulfur coals).

The conversion of SO_2 emissions to sulfate particles can contribute to the mass of fine particles in the atmosphere. However, it is important to note that the formation of sulfate from sulfur-trioxide (SO_3) emissions is a different phenomenon than the formation of the sulfate from the sulfur-dioxide (SO_2) emissions. Due to these differences, these emissions are controlled through different regulations by EPA.

Power plants have substantially reduced their SOx and NOx emissions that contribute to fine particulate levels in the air. Power plant emissions will continue to decrease over the next decade.

Through investments in scrubbers and operating strategies to accommodate lower-sulfur fuels, the U.S. electric power industry has cut its SO2 emissions while increasing power output and reliability. Analogous investments and operating changes to reduce NOx emissions have also been successful. By 2002, power plants had reduced SO2 emissions by more than 40% relative to 1980 levels (the reference year cited in the 1990 Clean Air Act Amendments) and had reduced NOx emissions by more than one-third, all while increasing power-plant output by over 60%. Power plant emissions reductions will continue throughout the remainder of the decade and beyond due to existing acid rain, ozone, and PM2.5 regulations and through new regulations and legislation being considered by EPA and the United States Congress.

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