

# Airborne Particulate Matter: Pollution Prevention and Control

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Airborne particulate matter (PM) emissions can be minimized by pollution prevention and emission control measures. Prevention, which is frequently more cost-effective than control, should be emphasized. Special attention should be given to pollution abatement measures in areas where toxics associated with particulate emissions may pose a significant environmental risk.

## Approaches to Pollution Prevention

### *Management*

Measures such as improved process design, operation, maintenance, housekeeping, and other management practices can reduce emissions. By improving combustion efficiency, the amount of products of incomplete combustion (PICs), a component of particulate matter, can be significantly reduced. Proper fuel-firing practices and combustion zone configuration, along with an adequate amount of excess air, can achieve lower PICs.

### *Choice of Fuel*

Atmospheric particulate emissions can be reduced by choosing cleaner fuels. Natural gas used as fuel emits negligible amounts of particulate matter. Oil-based processes also emit significantly fewer particulates than coal-fired combustion processes. Low-ash fossil fuels contain less noncombustible, ash-forming mineral matter and thus generate lower levels of particulate emissions. Lighter distillate oil-based combustion results in lower levels of particulate emissions than heavier residual oils. However, the choice of fuel is usually influenced by economic as well as environmental considerations.

### *Fuel Cleaning*

Reduction of ash by fuel cleaning reduces the generation of PM emissions. Physical cleaning of coal through washing and beneficiation can reduce its ash and sulfur content, provided that care is taken in handling the large quantities of solid and liquid wastes that are generated by the cleaning process. An alternative to coal cleaning is the co-firing of coal with higher and lower ash content. In addition to reduced particulate emissions, low-ash coal also contributes to better boiler performance and reduced boiler maintenance costs and downtime, thereby recovering some of the coal cleaning costs. For example, for a project in East Asia, investment in coal cleaning had an internal rate of return of 26% (World Bank 1991).

### *Choice of Technology and Processes*

The use of more efficient technologies or process changes can reduce PIC emissions. Advanced coal combustion technologies such as coal gasification and fluidized-bed combustion are examples of cleaner processes that may lower PICs by approximately 10%. Enclosed coal crushers and grinders emit lower PM.

## Approaches to Emission Control

A variety of particulate removal technologies, with different physical and economic characteristics, are available.

*Inertial or impingement separators* rely on the inertial properties of the particles to separate them from the carrier gas stream. Inertial separators are primarily used for the collection of medium-size and coarse particles. They include

settling chambers and centrifugal cyclones (straight-through, or the more frequently used reverse-flow cyclones). Cyclones are low-cost, low-maintenance centrifugal collectors that are typically used to remove particulates in the size range of 10–100 microns (mm); see Henderson-Sellers (1984). The fine-dust-removal efficiency of cyclones is typically below 70%, whereas electrostatic precipitators (ESPs) and baghouses can have removal efficiencies of 99.9% or more. Cyclones are therefore often used as a primary stage before other PM removal mechanisms. They typically cost about US\$35 per cubic meter/minute flow rate ( $\text{m}^3/\text{min}$ ), or US\$1 per cubic foot/minute (cu. ft./min); see Cooper and Alley (1986).

*Electrostatic precipitators (ESPs)* remove particles by using an electrostatic field to attract the particles onto the electrodes. Collection efficiencies for well-designed, well-operated, and well-maintained systems are typically in the order of 99.9% or more of the inlet dust loading. ESPs are especially efficient in collecting fine particulates and can also capture trace emissions of some toxic metals with an efficiency of 99% (Moore 1994). They are less sensitive to maximum temperatures than are fabric filters, and they operate with a very low pressure drop. Their consumption of electricity is similar to that of fabric filters (see Table 1). ESP performance is affected by fly-ash loading, the resistance of fly ash, and the sulfur content of the fuel. Lower sulfur concentrations in the flue gas can lead to a decrease in collection efficiency (Stultz and Kitto 1992). ESPs have been used for the recovery of process materials such as cement, as well as for pollution control. They typically add 1–2% to the capital cost of a new industrial plant.

*Filters and dust collectors (baghouses)* collect dust by passing flue gases through a fabric that acts as a filter. The most commonly used is the bag filter, or baghouse. The various types of filter media include woven fabric, needled felt, plastic, ceramic, and metal (Croom 1993). The operating temperature of the baghouse gas influences the choice of fabric. Accumulated particles are removed by mechanical shaking, reversal of the gas flow, or a stream of high-pressure air. Fabric filters are efficient (99.9% removal) for both high and low concentrations of particles but are suitable only for dry and free-flowing particles.

Their efficiency in removing toxic metals such as arsenic, cadmium, chromium, lead, and nickel is greater than 99% (Moore 1994).<sup>1</sup> They also have the potential to enhance the capture of sulfur dioxide ( $\text{SO}_2$ ) in installations downstream of sorbent injection and dry-scrubbing systems (Stultz and Kitto 1992). They typically add 1–2% to the capital cost of new power plants.

*Wet scrubbers* rely on a liquid spray to remove dust particles from a gas stream. They are primarily used to remove gaseous emissions, with particulate control a secondary function. The major types are venturi scrubbers, jet (fume) scrubbers, and spray towers or chambers. Venturi scrubbers consume large quantities of scrubbing liquid (such as water) and electric power and incur high pressure drops. Jet or fume scrubbers rely on the kinetic energy of the liquid stream. The typical removal efficiency of a jet or fume scrubber (for particles 10 mm or less) is lower than that of a venturi scrubber. Spray towers can handle larger gas flows with minimal pressure drop and are therefore often used as precoolers. Because wet scrubbers may contribute to corrosion, removal of water from the effluent gas of the scrubbers may be necessary. Another consideration is that wet scrubbing results in a liquid effluent. Wet-scrubbing technology is used where the contaminant cannot be removed easily in a dry form, soluble gases and wettable particles are present, and the contaminant will undergo some subsequent wet process (such as recovery, wet separation or settling, or neutralization). Gas flow rates range from 20 to 3,000  $\text{m}^3/\text{min}$ . Gas flow rates of approximately 2,000  $\text{m}^3/\text{min}$ . may have a corresponding pressure drop of 25 cm water column (Bounicore and Davis 1992).

## Equipment Selection

The selection of PM emissions control equipment is influenced by environmental, economic, and engineering factors:

*Environmental factors* include (a) the impact of control technology on ambient air quality; (b) the contribution of the pollution control system to the volume and characteristics of wastewater and solid waste generation; and (c) maximum allowable emissions requirements.

*Economic factors* include (a) the capital cost of the control technology; (b) the operating and maintenance costs of the technology; and (c) the expected lifetime and salvage value of the equipment.

*Engineering factors* include (a) contaminant characteristics such as physical and chemical properties—concentration, particulate shape, size distribution, chemical reactivity, corrosivity, abrasiveness, and toxicity; (b) gas stream characteristics such as volume flow rate, dust loading, temperature, pressure, humidity, composition, viscosity, density, reactivity, combustibility, corrosivity, and toxicity; and (c) design and performance characteristics of the control system such as pressure drop, reliability, dependability, compliance with utility and maintenance requirements, and temperature limitations, as well as size, weight, and fractional efficiency curves for particulates and mass transfer or contaminant destruction capability for gases or vapors.

Table 1 presents the principal advantages and disadvantages of the particulate control technologies discussed here. ESPs can handle very large volumetric flow rates at low pressure drops and can achieve very high efficiencies (99.9%). They are roughly equivalent in costs to fabric filters and are relatively inflexible to changes in process operating conditions. Wet scrubbers can also achieve high efficiencies and have the major advantage that some gaseous pollutants can be removed simultaneously with the particulates. However, they can only handle smaller gas flows (up to 3,000 m<sup>3</sup>/min), can be very costly to operate (owing to a high pressure drop), and produce a wet sludge that can present disposal problems (Cooper and Alley 1986). For a higher flue gas flow rate and greater than 99% removal of PM, ESPs and fabric filters are the equipment of choice, with very little difference in costs.

## Recommendations

For effective PM<sub>10</sub> control in industrial application, the use of ESPs or baghouses is recommended. They should be operated at their design efficiencies. In the absence of a specific emissions requirement, a maximum level of 50 milligrams per normal cubic meter (mg/Nm<sup>3</sup>) should be achieved.

For gases containing soluble toxics and where the gas flow rate is less than 3,000 m<sup>3</sup>/min, wet scrubbers may be used. Cyclones and mechanical separators should be used only as precleaning devices upstream of a baghouse or an ESP.

## Key Issues for Pollution Prevention and Control Planning

The principal methods for controlling the release of particulate matter are summarized here.

- Identify measures for improving operating and management practices.
- Consider alternative fuels such as gas instead of coal.
- Consider fuel-cleaning options such as coal washing, which can reduce ash content by up to 40%.
- Consider alternative production processes and technologies, such as fluidized bed combustion, that result in reduced PM emissions.
- Select optimal particulate removal devices such as ESPs and baghouses.

## Note

1. However, controlling emissions of many heavy metals, such as cadmium, lead, and mercury, that are present as trace elements in fuels is a difficult and largely unsolved problem.

## References and Sources

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**Table 1. Advantages and Disadvantages of Particulate Control Technologies**

<i>Advantages</i>	<i>Disadvantages</i>
<i>Inertial or impingement (cyclone) separators</i>	
<ul style="list-style-type: none"> <li>• Low capital cost (approximately US\$1/cu ft/min flow rate)</li> <li>• Relative simplicity and few maintenance problems</li> <li>• Relatively low operating pressure drop (for the degree of particulate removal obtained) in the range of approximately 5–15 cm (2–6 inches) water column</li> <li>• Temperature and pressure limitations imposed only by the materials of construction used</li> <li>• Dry collection and disposal</li> <li>• Relatively small space requirements</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively low overall particulate collection efficiencies, especially for particulate sizes below 10 mm</li> <li>• Inability to handle sticky materials</li> </ul>
<i>Wet scrubbers</i>	
<ul style="list-style-type: none"> <li>• No secondary dust sources</li> <li>• Relatively small space requirement</li> <li>• Ability to collect gases, as well as particulates (especially “sticky” ones)</li> <li>• Ability to handle high-temperature, high-humidity gas streams</li> <li>• Low capital cost (if wastewater treatment system is not required)</li> <li>• Insignificant pressure-drop concerns for processes where the gas stream is already at high pressure</li> <li>• High collection efficiency of fine particulates (albeit at the expense of pressure drop)</li> </ul>	<ul style="list-style-type: none"> <li>• Potential water disposal/effluent treatment problem</li> <li>• Corrosion problems (more severe than with dry systems)</li> <li>• Potentially objectionable steam plume opacity or droplet entrainment</li> <li>• Potentially high pressure drop—approximately 25 centimeters (10 inches) water column and horsepower requirements</li> <li>• Potential problem of solid buildup at the wet-dry interface</li> <li>• Relatively high maintenance costs</li> </ul>
<i>Electrostatic precipitators</i>	
<ul style="list-style-type: none"> <li>• Collection efficiencies of 99.9% or greater for coarse and fine particulates at relatively low energy consumption</li> <li>• Dry collection and disposal of dust</li> <li>• Low pressure drop—typically less than 1–2 cm (0.5 inch) water column</li> <li>• Continuous operation with minimum maintenance</li> <li>• Relatively low operation costs</li> <li>• Operation capability at high temperatures (up to 700°C, or (1,300°F) and high pressure (up to 10 atmospheres, or 150 pounds per square inch, psi) or under vacuum</li> <li>• Capability to handle relatively large gas-flow rates (on the order of 50,000 m<sup>3</sup>/min)</li> </ul>	<ul style="list-style-type: none"> <li>• High capital cost—approximately US\$160/square meter (\$15/square foot) of plate area</li> <li>• High sensitivity to fluctuations in gas stream conditions (flow rates, temperature, particulate and gas composition, and particulate loadings)</li> <li>• Difficulties with the collection of particles with extremely high or low resistivity</li> <li>• Relatively large space requirement for installation</li> <li>• Explosion hazard when dealing with combustible gases or particulates</li> <li>• Special precautionary requirements for safeguarding personnel from high voltage during ESP maintenance by de-energizing equipment before work commencement</li> <li>• Production of ozone by the negatively charged electrodes during gas ionization</li> <li>• Highly trained maintenance personnel required</li> </ul>
<i>Fabric filter systems (baghouses)</i>	
<ul style="list-style-type: none"> <li>• Very high collection efficiency (99.9%) for both coarse and fine particulates</li> <li>• Relative insensitivity to gas stream fluctuations and large changes in inlet dust loadings (for continuously cleaned filters)</li> <li>• Recirculation of filter outlet air</li> <li>• Dry recovery of collected material for subsequent processing and disposal</li> <li>• No corrosion problems</li> <li>• Simple maintenance, flammable dust collection in the absence of high voltage</li> <li>• High collection efficiency of submicron smoke and gaseous contaminants through the use of selected fibrous or granular filter aids</li> <li>• Various configurations and dimensions of filter collectors</li> <li>• Relatively simple operation</li> </ul>	<ul style="list-style-type: none"> <li>• Requirement of costly refractory mineral or metallic fabric at temperatures in excess of 290°C (550°F)</li> <li>• Need for fabric treatment to remove collected dust and reduce seepage of certain dusts</li> <li>• Relatively high maintenance requirements</li> <li>• Explosion and fire hazard of certain dusts at concentration (~50 g/m<sup>3</sup>) in the presence of accidental spark or flame, and fabric fire hazard in case of readily oxidizable dust collection</li> <li>• Shortened fabric life at elevated temperatures and in the presence of acid or alkaline particulate or gas constituents -Potential crusty caking or plugging of the fabric, or need for special additives due to hygroscopic materials, moisture condensation, or tarry adhesive components</li> <li>• Respiratory protection requirement for fabric replacement</li> <li>• Medium pressure-drop requirements—typically in the range of 10–25 centimeters (4–10 inches) in water column</li> </ul>

Source: Adapted from Bounicore and Davis 1992.

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