Sulfur Oxides: Pollution Prevention and Control

Traditionally, measures designed to reduce localized ground-level concentrations of sulfur oxides (SO_x) used high-level dispersion. Although these measures reduced localized health impacts, it is now realized that sulfur compounds travel long distances in the upper atmosphere and can cause damage far from the original source. Therefore the objective must be to reduce total emissions.

The extent to which SO_x emissions harm human health depends primarily on ground-level ambient concentrations, the number of people exposed, and the duration of exposure. Source location can affect these parameters; thus, plant siting is a critical factor in any SO_x management strategy.

The human health impacts of concern are short-term exposure to sulfur dioxide (SO_2) concentrations above 1,000 micrograms per cubic meter, measured as a 10-minute average. Priority therefore must be given to limiting exposures to peak concentrations. Industrial sources of sulfur oxides should have emergency management plans that can be implemented when concentrations reach predetermined levels. Emergency management plans may include actions such as using alternative low-sulfur fuels.

Traditionally, ground-level ambient concentrations of sulfur dioxide were reduced by emitting gases through tall stacks. Since this method does not address the problem of long-range transport and deposition of sulfur and merely disperses the pollutant, reliance on this strategy is no longer recommended. Stack height should be designed in accordance with good engineering practice (see, for example, United States, 40 CFR, Part 50, 100(ii).

Approaches for Limiting Emissions

The principal approaches to controlling SO_x emissions include use of low-sulfur fuel; reduction or removal of sulfur in the feed; use of appropriate combustion technologies; and emissions control technologies such as sorbent injection and flue gas desulfurization (FGD).

Choice of Fuel

Since sulfur emissions are proportional to the sulfur content of the fuel, an effective means of reducing SO_x emissions is to burn low-sulfur fuel such as natural gas, low-sulfur oil, or low-sulfur coal. Natural gas has the added advantage of emitting no particulate matter when burned.

Fuel Cleaning

The most significant option for reducing the sulfur content of fuel is called beneficiation. Up to 70% of the sulfur in high-sulfur coal is in pyritic or mineral sulfate form, not chemically bonded to the coal. Coal beneficiation can remove 50% of pyritic sulfur and 20–30% of total sulfur. (It is not effective in removing organic sulfur.) Beneficiation also removes ash responsible for particulate emissions. This approach may in some cases be cost-effective in controlling emissions of sulfur oxides, but it may generate large quantities of solid waste and acid wastewaters that must be properly treated and disposed of.

Sulfur in oil can be removed through chemical desulfurization processes, but this is not a widely used commercial technology outside the petroleum industry.

Selection of Technology and Modifications

Processes using fluidized-bed combustion (FBC) reduce air emissions of sulfur oxides. A lime or dolomite bed in the combustion chamber absorbs the sulfur oxides that are generated.

Emissions Control Technologies

The two major emissions control methods are sorbent injection and flue gas desulfurization:

- *Sorbent injection* involves adding an alkali compound to the coal combustion gases for reaction with the sulfur dioxide. Typical calcium sorbents include lime and variants of lime. Sodium-based compounds are also used. Sorbent injection processes remove 30–60% of sulfur oxide emissions.
- *Flue gas desulfurization* may be carried out using either of two basic FGD systems: regenerable and throwaway. Both methods may include wet or dry processes. Currently, more than 90% of utility FGD systems use a wet throwaway system process.

Throwaway systems use inexpensive scrubbing mediums that are cheaper to replace than to regenerate. Regenerable systems use expensive sorbents that are recovered by stripping sulfur oxides from the scrubbing medium. These produce useful by-products, including sulfur, sulfuric acid, and gypsum. Regenerable FGDs generally have higher capital costs than throwaway systems but lower waste disposal requirements and costs.

In wet FGD processes, flue gases are scrubbed in a liquid or liquid / solid slurry of lime or limestone. Wet processes are highly efficient and can achieve SO_x removal of 90% or more. With dry scrubbing, solid sorbents capture the sulfur oxides. Dry systems have 70–90% sulfur oxide removal efficiencies and often have lower capital and operating costs, lower energy and water requirements, and lower maintenance requirements, in addition to which there is no need to handle sludge. However, the economics of the wet and dry (including "semidry" spray absorber) FGD processes vary considerably from site to site. Wet processes are available for producing gypsum as a by product.

Table 1 compares removal efficiencies and capital costs of systems for controlling SO_x emissions.

Table 1. Comparison of SO_x Emissions Control Systems

System	*Percent SO_x reduction*	*Capital cost ($/kilowatt)*
Sorbent injection	30–70	50–100
Dry flue gas desulfurization	70–90	80–170
Wet flue gas sulfurization	>90	80–150

Source: Kataoka 1992.

Monitoring

The three types of SO_x monitoring systems are continuous stack monitoring, spot sampling, and surrogate monitoring. Continuous stack monitoring (CSM) involves sophisticated equipment that requires trained operators and careful maintenance. Spot sampling is performed by drawing gas samples from the stack at regular intervals. Surrogate monitoring uses operating parameters such as fuel sulfur content.

Recommendations

The traditional method of SO_x dispersion through high stacks is not recommended, since it does not reduce total SO_x loads in the environment. Natural gas is the preferred fuel in areas where it is readily available and economical to use. Methods of reducing SO_x generation, such as fuel cleaning systems and combustion modifications, should be examined. Implementation of these methods may avoid the need for FGD systems. Where possible and commercially feasible, preference should be given to dry SO_x removal systems over wet systems.

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