Cement Manufacturing

Industry Description and Practices

The preparation of cement involves mining; crushing, and grinding of raw materials (principally limestone and clay); calcining the materials in a rotary kiln; cooling the resulting clinker; mixing the clinker with gypsum; and milling, storing, and bagging the finished cement. The process generates a variety of wastes, including dust, which is captured and recycled to the process. The process is very energy-intensive, and there are strong incentives for energy conservation. Gases from clinker cooler are used as secondary combustion air. The dry process, using preheaters and precalciners, is both economically and environmentally preferable to the wet process because the energy consumption—200 joules per kilogram (J/kg)—is approximately half that for the wet process.

Certain solid waste products from other industries, such as pulverized fly ash (PFA) from power stations, slag, roasted pyrite residues, and foundry sand, can be used as additives in cement production.

Waste Characteristics

The generation of fine particulates is inherent in the process, but most are recovered and recycled. Approximately 10–20% of the kiln feed can be suspended in the kiln exhaust gases, captured, and returned to the feed. Other sources of dust emissions include the clinker cooler, crushers, grinders, and materials-handling equipment. When the raw materials have high alkali or chloride content, a portion of the collected dust must be disposed of as solid waste, to avoid alkali buildup. Leaching of the dust to remove the alkali is rarely practiced. Grinding mill operations also result in particulate emissions. Other materials-handling operations, such as conveyors, result in fugitive emissions.

Ambient particulate levels (especially at sizes less than 10 microns) have been clearly demonstrated to be related to health impacts. Gases such as nitrogen oxides (NO_x) and sulfur oxides (SO_x) are formed from the combustion of the fuel (oil and coal) and oxidation of sulfur present in the raw materials, but the highly alkaline conditions in the kiln can absorb up to 90% of the sulfur oxides. Heavy metals may also be present in the raw materials and fuel used and are released in kiln gases. The principal aim of pollution control in this industry is to avoid increasing ambient levels of particulates by minimizing the loads emitted.

Cement kilns, with their high flame temperatures, are sometimes used to burn waste oils, solvents, and other organic wastes. These practices can result in the release of toxic metals and organics. Cement plants are not normally designed to burn wastes, but if such burning is contemplated, technical and environmental acceptability needs to be demonstrated. To avoid the formation of toxic chlorinated organics from the burning of organic wastes, air pollution control devices for such plants should not be operated in the temperature range of 230–400°C. (For further details, see United States1991.)

Pollution Prevention and Control

The priority in the cement industry is to minimize the increases in ambient particulate levels by reducing the mass load emitted from the stacks, from fugitive emissions, and from other sources. Collection and recycling of dust in kiln gases is required to improve the efficiency of the operation and to reduce atmospheric emissions. Units that are well designed, well operated, and well maintained can normally achieve generation of less than 0.2 kilograms of dust per metric ton (kg/t) of clinker, using dust recovery systems. NO_x emissions should be controlled by using proper kiln design, low-NO_x burners, and an optimum level of excess air. NO_x emissions from a dry kiln with preheater and precalciner are typically 1.5 kg/t of clinker, as against 4.5 kg/t for the wet process. The nitrogen oxide emissions can be reduced further, to 0.5 kg/t of clinker, by afterburning in a reducing atmosphere, and the energy of the gases can be recovered in a preheater/precalciner.

For control of fugitive particulate emissions, ventilation systems should be used in conjunction with hoods and enclosures covering transfer points and conveyors. Drop distances should be minimized by the use of adjustable conveyors. Dusty areas such as roads should be wetted down to reduce dust generation. Appropriate stormwater and runoff control systems should be provided to minimize the quantities of suspended material carried off site.

SO_x emissions are best controlled by using low-sulfur fuels and raw materials. The absorption capacity of the cement must be assessed to determine the quantity of sulfur dioxide emitted, which may be up to about half the sulfur load on the kiln. Precalcining with low-NO_x secondary firing can reduce nitrogen oxide emissions.

Alkaline dust removed from the kiln gases is normally disposed of as solid waste. When solid wastes such as pulverized fly ash are used with feedstock, appropriate steps must be taken to avoid environmental problems from contaminants or trace elements.

Stormwater systems and storage areas should be designed to minimize washoff of solids.

Treatment Technologies

Mechanical systems such as cyclones trap the larger particulates in kiln gases and act as preconditioners for downstream collection devices. Electrostatic precipitators (ESPs) and fabric filter systems (baghouses) are the principal options for collection and control (achieving over 99% removal efficiency) of fine particulates. ESPs are sensitive to gas characteristics, such as temperature, and to variation in voltage; baghouses are generally regarded as more reliable. The overall costs of the two systems are similar. The choice of system will depend on flue gas characteristics and local considerations.

Both ESPs and baghouses can achieve high levels of particulate removal from the kiln gas stream, but good operation and maintenance are essential for achieving design specifications. Two significant types of control problem can occur: (a) complete failure (or automatic shutoff) of systems related to plant shutdown and start-up, power failures, and the like, leading to the emission of very high levels of particulates for short periods of time; and (b) a gradual decrease in the removal efficiency of the system over time because of poor maintenance or improper operation. The lime content of raw materials can be used to control sulfur oxides.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

The guidelines given below present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

A maximum emissions level of 50 milligrams per normal cubic meter (mg / Nm^3), equivalent to a maximum of 0.2 kg / t of clinker, for particulates in stack gases under full-load conditions is to be achieved. This emissions level is based on values that are routinely achieved in well-run plants. Maximum emissions levels for sulfur oxides are 400 mg / Nm^3; for nitrogen oxides, 600 mg / Nm^3.

Management's capacity to maintain the necessary operational and maintenance standards should be carefully evaluated. If necessary, training for plant personnel should be provided under the project. The EA and the prefeasibility or feasibility study should examine the effects of fugitive and stack emissions (including dust, sulfur oxides, and nitrogen oxides) on ambient air quality and implement measures to maintain acceptable ambient air quality levels.

Liquid Effluents

Normally, effluents requiring treatment originate from cooling operations or as stormwater. Treated effluent discharges should have a pH in the range of 6–9. Cooling water should preferably be recycled. If this is not economical, the effluent should not increase the temperature of the receiving waters at the edge of the mixing zone (or 100 meters, where the mixing zone is not defined) by more than 3° Celsius. If quantities of suspended solids in the effluent are high in relation to receiving waters, treatment may be required to reduce levels in the effluent to a maximum of 50 milligrams per liter (mg / l). Note that the effluent requirements are for direct discharge to surface waters.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

	Maximum allowable log equivalent (hourly measurements), in dB(A)	
Receptor	*Day (07:00–22:00)*	*Night (22:00–07:00)*
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Monitoring and Reporting

Frequent sampling may be required during start-up and upset conditions. Once a record of consistent performance has been established, sampling for the parameters listed in this document should be as described below.

Equipment for continuous monitoring of opacity levels (or particulates in the stack exhaust, whichever is cost-effective) should be installed. Measurement of the sulfur content of raw materials and fuel, and direct measurement of particulate, SO_x, and NO_x levels at the plant boundary levels, should be carried out at least annually. When operational upsets occur, the opacity of kiln and clinker cooler exhaust gases should be measured directly and corrective actions taken to maintain the opacity level of the stack gases below 10% (or an equivalent measurement).

The pH and temperature of the wastewater effluent should be monitored on a continuous basis. Suspended solids should be measured monthly if treatment is provided.

Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken.

Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The key production and control practices that will lead to compliance with emissions guidelines can be summarized as follows:

Give preference to the dry process with preheaters and precalciners.

Adopt the following pollution prevention measures to minimize air emissions:

- Install equipment covers and filters for crushing, grinding, and milling operations.
- Use enclosed adjustable conveyors to minimize drop distances.
- Wet down intermediate and finished product storage piles.
- Use low-NO_x burners with the optimum level of excess air.
- Use low sulfur fuels in the kiln.
- Operate control systems to achieve the required emissions levels.

Develop a strong unit or division to undertake environmental management responsibilities.

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