Multilateral Investment Guarantee Agency

Environmental Guidelines for

Cement Manufacturing

Industry Description and Practices

The preparation of cement includes 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 results in 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 (kg) is approximately half of 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 material 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 SO_x. Heavy metals may also be present in raw materials and fuel used and are thereby 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, the technical and environmental acceptability need 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* (see US government Federal Register Vol. 56, No. 35, February 21, 1991 for further details).

Pollution Prevention and Control

The priority in the cement industry is to minimize the increase 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 the atmospheric emissions. Well designed, operated and maintained units normally can achieve less than 0.2 kilograms (kg) of dust per metric ton (kg/t) of clinker using dust recovery systems. NO_x emissions should be controlled by the use of proper kiln design, low NO_x burners and use of an optimum level of excess air. The NO_x emissions from a dry kiln with preheater and precalciner is typically 1.5 kg/t of clinker compared to 4.5 kg/t for the wet process. The NO_x emissions can be reduced further to 0.5 kg/t of clinker by after burning in a reducing atmosphere and energy of the gases 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.

Sulfur dioxide emissions are best controlled by the use of low sulfur fuels and low sulfur 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 NO_x emissions.

Alkaline dust removed from the kiln gases is normally disposed of as solid waste. *When solid wastes such as pulverized fly ash (PFA) 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 wash-off 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 voltage variation. Baghouses are generally regarded as more reliable. The overall costs of the two systems are similar; the choice of system will depend on the 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 to achieve design specifications. Two significant types of control problems can occur: complete failure (or automatic shut-off) of systems related to plant shut-down and start-up, power failures, and the like, leading to the emission of very high levels of particulates for short periods of time; and gradual decrease in the removal efficiency of the system over time because of poor maintenance or improper operation. Lime content of raw materials can be used to control sulfur oxides.

Emission Guidelines

Emission levels for the design and operation of each project must be established through the Environmental Assessment (EA) process, based on country legislation and the *Pollution Prevention and Abatement Handbook* as applied to local conditions. The emission levels selected must be justified in the EA and acceptable to MIGA.

The following guidelines present emission levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance, including MIGA guarantees; any deviations from these levels must be described in the project documentation.

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 emission level is based on values that are routinely achieved in well-run plants. Maximum emission levels for sulfur oxides are 400 mg/Nm^3; for NO_x 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 Environmental Assessment and (pre)feasibility study should examine the effects of fugitive and stack emissions (including dust, SO_x, and NO_x) on ambient air quality and implement measures to maintain acceptable ambient air quality levels.

The Environmental Assessment and (pre)feasibility study examine the effects of stack and fugitive emissions (including dust, SO_x and NO_x) on ambient air quality and analyze measures that may be required to control them.

Liquid Effluents

Normally effluents requiring treatment result from cooling operations or as storm water. Treated effluent discharges should have a pH in the range of 6-9. Cooling waters should preferably be recycled. If this is not economical, then the effluent should not increase the temperature of the receiving waters at the edge of mixing zone (or 100 meters where the mixing zone is not defined) by more than 3 degrees 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: Effluent requirements are for direct discharge to surface waters.

Ambient Noise

Noise abatement measures should achieve either the following levels or a maximum increase in background levels of 3 dB(A). Measurements are to be taken at noise receptors located outside the project property boundary.

Ambient Noise

	Maximum Allowable L_{eq} (hourly), in dB(A)	
Receptor	Daytime 07:00 - 22:00	Nighttime 22:00 - 07:00
Residential; institutional; educational	55	45
Industrial; commercial	70	70

The emission requirements given here can be consistently achieved by well-designed, well-operated and well-maintained pollution control systems.

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 above should be as detailed below.

Equipment for continuous monitoring of opacity levels (or particulates in the stack exhaust whichever is cost-effective) should be installed. Sulfur content of raw materials , Direct measurement of particulate, SO_2 and NO_2 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. These should be reported to the responsible authorities and relevant parties, as required, and provided to MIGA if requested.

Key Issues

The following box summarizes the key production and control practices that will lead to compliance with emission guidelines:

- Give preference to the dry process with preheater 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 optimum level of excess air.
  - Use low sulfur fuels in the kiln.
  - Operate control systems to achieve the required emission levels.
- Develop a strong unit/division to undertake environmental management responsibilities.

Further Information

The following are suggested as sources of additional information (these sources are provided for guidance and are not intended to be comprehensive):

Bounicore, A.J. and W.T. Davis. 1992. *Air Pollution Engineering Manual*. New York: Van Nostrand Reinhold.

European Community (EC). December 7, 1989. Technical note on "Best Available Technologies Not Entailing Excessive Cost for the Manufacture of Cement." Paper presented to BAT Exchange of Information Committee, Brussels, Belgium.

Fog, M.H. and K.L. Nadkarni. 1983. “Energy Efficiency and Fuel Substitution in the Cement Industry with Emphasis on Developing Countries.” A World Bank Technical Paper, Industry and Finance, Volume 2. The World Bank, Washington, DC.

Sittig, Marshall. 1975. Pollution Control in the Asbestos, Cement, Glass, and Allied Mineral Industries. London: Noyes Data Corporation.

World Bank, Environment Department. 1996. "Pollution Prevention and Abatement: Cement Manufacturing." Technical Background Document.