Air Pollutant Emission and Control Techniques for the Cement Manufacturing Industry

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Abstract-- India is undergoing a sudden surge of industrialization in the last few decades, which has led to the economic and social development of India, as a developing nation, coupled with high rate of urban migration to the big cities. Hence, besides steel production and power generation, cement production is the most important industry in India, due to increase in demand for cement in the construction industry in India, due to increase in demand for cement in the construction industries. The major pollutant to air from cement production are Methane, Fume, Dust, Nitrogen oxide, Sulphur oxide, Carbon oxide and Carbon dioxide, which are responsible for global warming potential, which can harm the environment and are also harmful to human and plant health through respiration. The air quality was assessed based on new national ambient air quality standard. $PM_{2.5}$,PM_{10}, SO_2,and NO_2 are selected parameters. The average value of PM10 was found beyond the permissible limit at near power plant the outcome of the study has been presented in the form of air quality index. AQI was found moderate for PM_{10} and $PM_{2.5}$, SO_2 and NO_2 were observed in good range. Excess of PM_{10} is control in water spray system, road cleaning vehicles, choosing cleaner fuel system and consider alternative fuels such as gas instead of coal by reduced the coal. This research work presents data of the ambient air quality status of Ariyallur district of Tamilnadu, India. Modern ESP are designed to have high collection efficiencies of all types of fly ash, some are marketed as applicable to worldwide coal firing: collection efficiencies are now up to 99%.

Keywords--- pollutant, cement, Ariyallur, air quality and dust.

I. INTRODUCTION

The cement industry contributes significantly to the imbalances of the environment: in particular air quality. The key environmental emissions are nitrogen oxides (NO_x), Sulphur dioxide (SO_2) and grey quality. Industrial plant smokestacks from cement and construction companies are some of the biggest contributors to poor air quality, especially in urban developments. As of 2008, the cement industry alone was reported to produce 5% of total greenhouse gasses in the atmosphere (Air Quality Resources). The principal aim in pollution control 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. This paper looks at emission and control of gaseous and particulate matter. Concentration of CO_2, NO_x, CO and SO_2 in the flue gas emanating from the kiln stack was also measured by permanently installed gas sensors. Average concentrations of CO_2, CO, NO_x and SO_2 in the kiln stack emission were 15.9% 218.5 mg/Nm^3 *(Normal cubic meter), 1119 mg/Nm^3 and 3.7 earlier report done for cement kilns. These concentrations amounted to emissions of 160.1Mt/h (Mt-megaton) of CO_2 and 123,623 and 2.1 kg/h emissions of CO_2, CO, NO_x and SO_2 respectively.

The emission standards for existing cement industry with plant capacity of 200 tonnes per day and less in all sections for protected area is 250 mg/Nm^3 and in other area 400 mg/Nm^3. Similarly the standard for plant capacity of greater than 200 tonnes per day in all sections for protected area is 150 mg/Nm^3 and in other area 250 mg/Nm^3. About 60 percent of emissions caused by making cement are from this chemical process alone.

1.1 Cement Production Technology

Cement is produced from raw materials such as limestone, chalk, shale, clay, and sand. These raw materials are quarried, crushed, finely ground, and blended to the correct chemical composition. After the mining, grinding and homogenization of raw materials, the process of calcinations is followed by burning the resulting calcium oxide together with silica, alumina and ferrous oxide at high temperatures to form clinker; the clinker is then ground or milled together with other constituents (as gypsum, slag etc.) to produce cement. The main stages in cement production can thus be discussed under the following sub-headings:

1.1.1 Quarrying (Raw material acquisition)

Most of the raw materials used are extracted from the earth through mining and quarrying and can be divided into the following groups: lime, silica, alumina, and iron. Limestone (calcium carbonate – $CaCO_3$) is the predominant raw material therefore most plants are situated near a limestone quarry or receive this material from a source via inexpensive transportation. The plant must minimize the transportation cost since one third of the limestone is converted to carbon dioxide (CO_2) during the pyro-processing and is subsequently lost. Quarry operations consist of drilling, blasting, excavating, handling, loading, hauling, crushing, screening, stockpiling, and storing.

1.1.2 Raw Materials Preparation (Raw Milling and Fuels Preparation)

Raw milling involves mixing the extracted raw materials to obtain the correct chemical configuration, and grinding them to achieve the proper particle-size to ensure optimal fuel efficiency in the cement kiln and strength in the final concrete product. Three types of processes may be used: the dry process, the wet process, or the semidry process. If the dry process is used, the raw materials are dried using impact dryers, drum dryers, paddle-equipped rapid dryers, or air separators, before grinding, or in the grinding process itself. In the wet process, water is added during grinding. In the semidry process the materials are formed into pellets with the addition of water in a pelletizing device.

1.1.3 Clinker Burning

In pyro-processing, the raw mix is heated to produce cement clinkers. Clinkers are hard, grey, spherical nodules with diameters ranging from 0.32 - 5.0cm created from the chemical reactions (sintering) between the raw materials. The pyro-processing system involves three steps: drying or preheating, calcining (a heating process in which calcium oxide is formed), and burning (sintering). The pyro-processing takes place in the burning/kiln department. The raw mix is supplied to the system as a slurry (wet process), a powder (dry process), or as moist pellets (semidry process). All systems use a rotary kiln and contain the burning stage and all or part of the calcining stage. For the wet and dry processes, all pyro-processing operations take place in the rotary kiln, while drying and preheating and some of the calcinations is performed outside the kiln on moving grates supplied with hot kiln gases.

1.1.4 Cement Grinding

This stage is also known as finish milling. Here the clinker is ground with other materials (which impart special characteristics to the finished product) into a fine powder. Gypsum and/or natural anhydrite are added to regulate the setting time of the cement. Other chemicals, such as those which regulate fluidity or air entrainment, may also be added. Material that has not been completely ground is sent through the system again.

1.1.5 Cement Packaging and Dispatch

The finished product is transferred using bucket elevators and conveyors to storage silos. Most of the cement is transported to customers in bulk by railway, trucks, and in bags (normally 50kg bags). Cement is mostly used in mortar and concrete in the construction industry.

II. ENVIRONMENTAL IMPACTS OF CEMENT MANUFACTURES

Cement manufacturing is a “high volume process” and correspondingly requires adequate quantities of resources, that is, raw materials, thermal fuels and electrical power. The main environmental (air quality) impacts of the manufacture of cement in general are related to the categories discussed below.

2.1 Gaseous Atmospheric Emissions of Co_2, No_x, So_2, Volatile Organic Compounds (Voc_s) and Others

Carbon dioxide is released during the production of clinker, a component of cement, in which calcium carbonate ($CaCO_3$) is heated in a rotary kiln to induce a series of complex chemical reactions. Specifically, co2 is released as a by-product during calcinations, which occurs in the upper, cooler end of the kiln or a precalciner, at temperatures of 600-900^o C and results in the conversion of carbonates to oxides. The simplified stoichiometric relationship is as follows:

$$CaCO_3 + HEAT \rightarrow CaO + CO_2$$

Additional air pollutants emitted include such materials as sulphur oxides and nitrogen oxides generated from the kiln and drying processes. Sulphur dioxide is generated from the sulphur compounds in the ores and the combusted fuel and varies in amount produced from plant to plant. The efficiency of particulate control devices is inconclusive as the result of variables such as feed sulphur content, temperature, moisture, and feed chemical composition, in addition to alkali and sulphur content of the raw materials and fuel. The combustion of fuel in rotary cement kilns generates nitrogen oxides from the nitrogen in the fuel and incoming combustion air. The amount emitted depends on several factors including fuel type, nitrogen content, and combustion temperature. Both sulphur dioxide and some of the nitrogen oxide react with the alkaline cement and are removed from the gas stream. Volatile organic carbon compounds (VOCs) are a class of chemicals that are emitted directly to the air as a result of evaporation or another type of volatilization. Sources include stored gasoline, stored solvents and other industrial chemicals, and certain industrial processes. Incomplete combustion of fuels of many types is also an important source of VOC discharge to the ambient air. The principal harmful effects of VOCs are toxicity, possible contribution to smog via photochemical reactions in the atmosphere and possible contribution to the "greenhouse effect" and consequent global warming.

2.2 Dust

Dust emissions originate mainly from the raw mills, the kiln system, the clinker cooler and the cement mills. A general feature of these process steps is that hot exhaust has or exhaust air is passing through pulverized material resulting in an intimately dispersed mixture of gas and particulates. The nature of the particulates generated is linked to the source material itself, that is raw materials (partly calcined), clinker or cement. Dust emissions have been linked to respiratory problems such as Tuberculosis.

2.3 Bad Odour

Foul smell is sometimes a direct result of the gases emitted during cement manufacturing. Moreover, since cement manufacture has life threatening impacts to plants and animals, the manufacturing process then directly and indirectly gives rise to offensive smells as the dead plants and animals decay.

III. LITERATURE REVIEW

(Chandrasekhran 1998) The main environmental issues associated with cement production are emission to air and energy use. The energy use by cement industry is estimated at about 2% of global energy consumption 5% of global energy consumption 5% of global manmade carbon dioxide emissions originated from cement production.

(Shrujan et al.,) Cement is an essential component of infrastructure development and most important input of construction industry, particularly in the government's socioeconomic growth and development. While industrialization is an essential feature of economic growth in developing countries, industrial practices may also produce adverse environmental health consequences through the release of air and water pollutants and the disposal of hazardous wastes. The dust, gases, fumes produced by cement manufacturing units is considered one of the most hazardous pollutants which affect the surrounding environment. By adoption of appropriate technology and computer modeling, industry will not only reduce production waste but also comply with legislation to do with environmental protection. The main purpose of this review is to provide the details regarding the environmental pollution caused by cement industries and suggest measures to control the same.

(Garg et al 2001; Kumar and Joseph 2006) Many projects are being constructed including multistoried residential building high. Raise commercial buildings as well as many other infrastructure projects due to the availability of raw material necessary for the manufacturing of cement.

(Walter L. Greer) The control of pollutants from cement kilns is becoming a major concern in the Americas. Emission limits for HCL, mercury (Hg), particulate matter (PM), hydrocarbons, dioxins, furans and nitrogen oxides (NO_x) have just been set to Maximum Achievable Control Technology (MACT) requirements in the United States. New limits for sulfur dioxide (SO_2) emissions, H_2SO_4 and NH_3 are anticipated. The capture of CO_2 may also be required. This paper reviews some of these pollutants, the emission limits and the control technologies.

(Hesham G. Ibrahim) Emissions of NO_x from both cement plants can mainly be attributed to large quantity of excess air exceeding the optimum values; however, raw materials from another source of NO_x. Since the used fuel is natural gas high rates of emissions should not occur and high rates of NO_x cannot be linked to the fuel. Sulfur dioxide emissions are largely attributed to the raw materials adsorbed by the cold feed in the pre-heater and the remainder is released with the flue gases in presence of large quantities of excess air. Occurrence of excessive particulate emissions suggests a presence of high rates of CO in the ESP result from inadequate operational procedures that reduces the performance of each electrostatic precipitator.

IV. AIR QUALITY INDEX

Air quality index values are divided into six ranges and each range is assigned a descriptor and a colour code. Standardized public health advisories are associated with each API range. These are as follows, "Good": AQI is 0-50. Air quality is considered satisfactory and air pollution poses little or no risk. “Moderate” AQI is 51 - 100. Air quality is acceptable; however for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms. “Unhealthy for Sensitive Groups” AQI is 101 -150. Although general public is not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air. “Unhealthy” AQI is 151 – 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects. “Very Unhealthy” AQI is 201 – 300. This would trigger a health alert signifying that everyone may experience more serious health effects. “Hazardous” AQI is greater than 300. This would trigger a health warning of emergency conditions. The entire population is more likely to be affected.

V. METHODS AND MATERIALS COLLECTION

The study was conducted at cement industry. Samples are collected for 8 hrs at each site for every month at the time form 9AM to 5PM. Six sampling sites for ambient air monitoring were selected. They are near main gate, power plant, coal mill and dispensary. Monitored parameters were PM2.5, PM10 and gaseous pollutants such as SO_2 and NO_2. Repairable Dust Sampler Envirotech APM 460(NL) was used for air sampling and analyzed as per standard methods. Air Quality index (AQI) was calculated.

5.1 Methods of Measurement

- Sulphur dioxide emission was calculated by using, improved west and Geak method.
- jacob and Hoochheiser Modified (NaOH-Na ASO_2) method for Nitrogen di oxide.
- High volume sampling method for particulate matter 2.5.
- Respirable particulate matter sampler for particulate matter 10.

5.2 Study Area

Ariyalur District is an administrative district in the state of Tamil_Nadu in India. The district headquarters is located at Ariyalur. The district encompasses an area of 1,949.31 km² and had a population of 752,481 as per the 2011 census. There are 7 cement factories available in ariyalur district. There are about 2 cement industries: madras cements and dalmia cement. It is facing multifarious problems of environmental pollution due to technological and industrial development and cement plant having a total productions capacity 3.25 million tons per annum is located at 30 km ion the perambalur district. This study is mainly based on the how to reduce the cement industries pollutants that affect the air.

VI. RESULTS AND DISCUSSION

TABLE 6.1
National Ambient Air Quality Standards

Pollutant	Average weight	Concentration in ambient air	
		Industrial and residential area	Sensitive area
PM_{10}	Annual average	60µg/m³	60µg/m³
	24hrs	100µg/m³	100µg/m³
$PM_{2.5}$	Annual average	40µg/m³	40µg/m³
	24hrs	60µg/m³	60µg/m³
SO_2	Annual average	40µg/m³	30µg/m³
	24hrs	80µg/m³	80µg/m³
NO_2	Annual average	50µg/m³	20µg/m³
	24hrs	80µg/m³	80µg/m³

TABLE 6.2
Average Ambient Air Pollution Level in Cement Industries In Ariyallur District

Cement Industries Name	Pollutants in µg/m³			
	NO_x	SO_x	$PM_{2.5}$	PM_{10}
Madras cements	46	44	25	79
Dalmia cements	19	16	14	69

TABLE 6.3
Air Quality Index – Range and Colour From WHO

Air quality index value (µg/m^3)	**Level of health concern**	**Colour**
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive groups	Orange
151-200	Unhealthy	Red
201-300	Very unhealthy	Purple
301-500	Hazardous	Merrown

TABLE 6.4

Emission Concentration (µg/M^3) at Various Stations

Parameters (µg/m^3)	**Standard limit (µg/m^3)**	**Sampling**	**Stations**			
			Main gate	**Near power plant**	**Near coal mill**	**Near dispensary**
SO_2	80	1	13.2	17.5	20.5	18.2
		2	19.2	19.2	21.2	14.6
		3	14.6	16.5	22.2	10.2
		4	17.5	18.8	18.2	11.5
		Average	16.1	18	20.5	13.6
NO_2	80	1	15	16.2	23.2	22.2
		2	15.5	13.8	21.5	25.5
		3	13.2	15	18.5	20.4
		4	20	25.6	20.5	19.5
		Average	15.9	17.6	20.9	21.9
$PM_{2.5}$	500	1	308	360	365	222
		2	255	290	345	356
		3	296	375	330	264
		4	326	350	220	268
		Average	296.2	343.7	315	277.5
PM_{10}	100	1	42	101	96	69
		2	75	120	97	70
		3	68	99	100	60
		4	30	90	99	52
		Average	53.7	102.5	98	62.75

TABLE 6.5

Air Quality Index Value for Cement Industries

Pollutants	**AQI value**	**Levels of health concern**	**Colour**
SO_2	22	Good	Green
NO_x	20	Good	Green
$PM_{2.5}$	16	Good	Greem
PM_{10}	60	Moderate	Yellow

6.6 DISCUSSION

Ambient air quality was assessed using six monitoring stations inside the cement industries the studies have clearly revealed the levels of air pollutants for $PM_{2.5}$, PM_{10}, NO_x and SO_2. The values are observed to be very much below National Ambient Air Quality Standards except the PM_{10} that is the residential area.

VII. CONTROL SYSTEMS

The various techniques that can be used to control pollution in the cement manufacturing process can be easily identified by considering the major process stages as outlined below

7.1 Raw Materials Acquisition and Handling

During raw material acquisition the primary air pollutant emitted is particulate matter. Particulate matter is emitted from the quarrying, handling, loading, unloading and transport of raw materials. The following methods are used to control particulate emissions generated from the quarry and handling of raw materials:

1. Fabric filters (pulse-jet or reverse- air/shaker)
2. Equipment enclosures
3. Water sprays – to suppress dust
4. Mechanical collectors
5. Chemical dust suppressants
6. Paving

Dust that is collected by these means is restored to the process. This therefore means that the reduce, reuse, recycle and recover (4Rs) techniques can be employed to minimize and manage waste during raw materials acqusistion.

7.2 Clinkerisation (Pyro-Processing)

The main pyro-processing system emissions are nitrogen, carbon dioxide, water, oxygen, nitrogen oxides, sulphur oxides, carbon monoxide, and hydrocarbons. Cement kiln dust (CKD) is also produced. The cement kiln itself has been designated as best available control technology (BACT) for the control of SO_2. The highly alkaline conditions of the kiln system enable it to capture up to 95% of the possible SO_2 emissions. However, if sulphide (pyrites) is this absorption rate can decline to as low as 50%. Therefore, sulphur emissions can be decreased through careful selection of raw materials. Options are available to move from coal fuel to oil or gas fuel as these will result in consider lower sulphur oxides and carbon monoxide emissions. Possible areas of exploitation for the control of NO_x are as follows:

1. Stable kiln operation (reduces long term NOx emissions)

2. Staged combustion for precalciner kilns;

3. Recirculation of the flue gas (oxygen deficient air in the rotary kiln); and

4. Alternative/low-nitrogen fuels.

7.3 Cement Loading and Dispatch

In the shipping department particulate matter is emitted from the silos and the handling and loading operations. Active and passive fabric filters can be used to collect this dust. To ensure dust-free loading onto the transport vessel a flexible loading spout consisting of concentric tubes is used. The outermost tube seals the delivery spout to the transport vehicle. The product is than delivered through the inner tube and displaced air drawn up the outer tube to a filter. At distribution terminals, fabric filters are again used and the collected dust is returned to the product.

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