

# **TREATMENT OF WASTE GENERATED FROM CEMENT INDUSTRY AND THEIR TREATMENT- A REVIEW**

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## **Abstract**

Cement manufacturing Industries is one of the key sectors of the Indian Economy has been rapidly growing at a rate over 8% and it is estimated to grow more. Cement is a crucial product for the society delivering easy secure reliable modern housing and infrastructure. The contribution of pollution towards the environmental degradation is increasing at an alarming rate. A good number of cement plants have made significant efforts in controlling and regulating the emissions by well organized control measure like Electro Static Precipitator (ESP) and Bag Filter APCD devices and these plants are maintaining their pollution level. Fugitive emissions (emission not from stack) in cement plant is still is a major problem and are waiting for new effective technologies.

This review mainly focuses on overview of the pollution of air and water and solid waste in cement industries and the main sources of environmental pollution in cement industries. The review carried out here shows techniques which are in practice in present to treat the waste (air, water and solid) generated from cement industry including co-processing and pollution control at each stage of cement production. Several countries, including India, have introduced strict ecological and environmental standard for cement industries. With more strict controls expected in the future, it is essential that control measures be implemented to minimize effluent problems.

**Keywords:** Cement , air ,water , solid waste

## **Introduction:-**

Cement manufacturing Industries is among the major sectors of the Indian Economy. Infrastructure development is a direct sign of a country's growth. After 90's there is specific focus of Government on Infrastructure development, which has also increases the requirement of cement. The Cement industry is experiencing phenomenal growth because of rise in construction activities. As growth rate of cement sector has been projected 10% during 11th Plan Period (2007-2012) by planning commission of Indian Govt<sup>[1]</sup>. due to this it is concluded that there will be increase in cement plants and more number of cement plant would flourish and the existing may incorporate new kilns to increase their existing capacities. Usage of more fly ash, slag etc is also increasing to create additional production capacity<sup>[2][3]</sup>. As the demand is increasing day by day, most cement plants are trying to achieve higher production levels by making extra efforts, even if it require to stretch the existing facilities at their disposal and by adding extra capacities.

As there is rapid urbanization and industrialization going on, Environmental pollution becomes a major topic of discussion and attracts a lot of attention as it is the major problem associated with rapid industrialization, urbanization. In developing countries construction work is going at very high rate and cement requirement is at peak. Cement industries are among the most polluting industries and according central pollution control board (CPCB) comes under red category<sup>[4]</sup>. The air of neighboring environment around the cement plant is being polluted by many effluents coming out of cement plants. Highly toxic and carcinogenic pollutants are emitted from cement kiln. Adverse respiratory health effects are also seen in the people exposed to cement dust. Considerable efforts have been made in controlling the stack emissions using most efficient control systems like bag filter and ESP by most cement plants & these plants generally meet the environmental regulations for stack emissions. However, an area which still remains a point of concern is of fugitive emissions from various sources in cement plants. There have been no environmental regulations/guidelines in terms of preventing/controlling fugitive emissions from the regulatory bodies to curb fugitive pollution till date. Initiatives in controlling fugitive emissions have been taken by many cement plants though with varying degree of effectiveness. However to satisfactorily control the fugitive emissions more efforts are required in this area on sustainable basis.

## **An overview of Cement Sector in India**

The cement industries sector has about 132 cement plants with an installed capacity of 166 MTPA<sup>[5]</sup>. Most of cement production is governed by "private sector" units and the share of public sector is very less (6%). Approximate 54 private companies hold the owner-ship of cement production, in which 5 private sectors companies possess almost half the units (M/s ACC, M/s Ultratech, M/s Gujarat Ambuja, M/s Grasim Industries and M/s India Cements). Mostly cement manufacturing industries produce cement using dry process (approx. 96%) and very few use the wet and semi dry process. Most of the unit produces Portland cement while very few are involved in white cement.

## **Health effects of Cement Dust**

The dust generated from cement plant could be categorized as inert dust or nuisance dust & can be defined as dust that contains less than 1% quartz. Cement dust contains heavy metals like nickel,

cobalt, lead, and chromium, pollutants hazardous to the biotic environment<sup>[6]</sup>, with adverse impact for vegetation, human and animal health and ecosystems. Cement dust irritates the skin, the mucous membrane of the eyes and the respiratory system<sup>[7]</sup>. Any reaction that may occur from such dust is potentially reversible. However, excessive concentrations of nuisance dust in the workplace may reduce visibility, may cause unpleasant deposits in eyes, ears, and nasal passages, and may cause injury to the skin or mucous membranes by chemical or mechanical-action<sup>[1]</sup>. From an occupational health point of view, dust is classified by size into three primary categories: - Respirable, Inhalable & Total. Respirable dust refers to those dust particles that are small enough to penetrate the nose and upper respiratory system and deep into the lungs. Particles that penetrate deep into the respiratory system are generally beyond the body's natural clearance mechanisms of cilia and mucous and are more likely to be retained. The Inhalable dust is that size fraction of dust, which enters the body, but is trapped in the nose, throat, and upper respiratory tract. The median aerodynamic diameter of this dust is about 10 microns. Total dust includes all airborne particles, regardless of their size or composition. Proper waste management and treatment system is required for effluent coming out from cement industries so adverse effect of these pollutants can be minimized to maintain environment and to reuse the waste material in other process.

#### **Cement manufacturing process:-**

Along with Portland cement masonry cement also produced by cement industries. Texture of Portland cement is a fine, composed of tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, in addition have some forms of calcium sulfate. Portland cement manufacturing is based on its use and chemical and physical properties desired. Most common of these are I-V types. Portland cement plants have low shutdown time for maintenance, thereby increases its production ability. Main steps of cement manufacturing are these:-

1. Raw Material Acquisition:-Raw materials are extracted from the earth through mining and quarrying includes: lime, silica, alumina, and iron. To obtain limestone a major component, most of the plants are situated near to limestone quarry. The expanse of transportation must be minimize since one third of the limestone is subsequently lost during Pyroprocessing (converted into CO<sub>2</sub>)[1]. Quarry follows drilling, blasting, excavating, handling, loading, hauling, crushing, screening, stockpiling, and storing.
2. Raw Milling:- Mixing to obtain correct chemical configuration with proper particle size, strength and efficiency comes under raw milling. It can be achieved by any of three processes mentioned: the dry process, the wet process, or the semidry process. In dry process the raw materials are dried using impact dryers, drum dryers, paddle-equipped rapid dryers, air separators, or autogenous mills, before grinding, or in the grinding process itself. In the wet process, water is added during grinding. Addition of water in a pelletizing device comes under semidry process.
3. Pyroprocessing:- Clinker is produced by heating raw mix in pyro-processing. It forms hard, gray, spherical clinker nodules with diameters ranging from 0.32 - 5.0 cm (1/8 - 2") [2]. Steps during pyro-processing are: drying or preheating, calcining (a heating lead to calcium oxide formation), and burning (sintering). Burning/kiln department responsible for pyroprocessing where raw mix is supplied to the system as a slurry (wet process), a powder (dry process), or

as moist pellets (semidry process). Most process are carried out in the rotary kiln, while drying, preheating and some of the calcination is performed outside the kiln on moving grates supplied with hot kiln gases.

4. **Clinker Cooling:-** It recovers up to 30% of kiln system heat, preserves the ideal product qualities, and enables the cooled clinker to be maneuvered by conveyors. The most common are reciprocating grate, planetary, and rotary. Air sent through the clinker to cool it is directed to the rotary kiln where it nourishes fuel combustion [3]. The fairly coarse dust collected from clinker coolers is comprised of cement minerals and is restored to the operation. Based on the cooling efficiency and temperature, air used in this cooling process is approximately 1-2 kg/kg of clinker.
5. **Clinker Storage:-** Normal storage capacity of clinker is 5-25% of its annual clinker production but it varies according to market. The clinkers are transferred to the finish mill with the help of conveyers and bulk elevators.
6. **Finish Milling:-** The clinker is ground with other materials (which impart special characteristics to the finished product) into a fine powder and upto 5% gypsum and/or natural anhydrite is added to regulate the setting time of the cement[4]. Other chemicals that regulate flowability or air entrainment can be added. After preliminary size via Roll Crusher materials are sent through ball or tube mills (rotating, horizontal steel cylinders containing steel alloy balls) which perform the remaining grinding. The grinding process occurs in a closed system with an air separator that divides the cement particles according to size. Partially or incomplete materials are loop in production system again.
7. **Packing and Loading:-**The finished product is being transferred via bucket elevators and conveyors, but major part is carried out by railway, truck, or barge, or in 50 kg multi walled paper bags. Primarily bags are used in packing of masonry cement. Sometimes distribution terminals are used as an intermediary holding prior to market and they also have similar type of conveyor system for loading the cement.

### **Air Emissions**

In cement and lime manufacturing air emissions are generated by the usage and storage of intermediate and finishing materials, and by the procedure of kiln systems, clinker coolers, and mills. In cement manufacturing several types of kilns are currently being used. Preheater– precalciner (PHP), preheater (PH), long-dry (LD), semidry, semi-wet, and wet process kilns are among them. In terms of environmental performance PHP kilns are generally favored. While shaft kilns, which are generally only economically viable for small plants are still in operation and with the renewal of installations are being phased out.

### **Nitrogen Oxides:-**

Nitrogen oxide ( $\text{NO}_x$ ) emissions are generated in the high temperature combustion process of the cement kiln<sup>[8]</sup>. The following prevention and control techniques are recommended.

- Maintaining secondary air flow as low as possible (e.g. oxygen reduction)<sup>[8]</sup>.
- Using low NOX burners to avoid localized emission hot spots<sup>[9]</sup>.
- Developing a staged combustion process, as applicable in preheater-precalciner (PHP) and pre-heater (PH) kilns<sup>[10]</sup>.

- Employing flame cooling by adding water to the fuel or directly to the flame (e.g. temp. decrease and hydroxyl radical concentration increase)<sup>[11]</sup>.

### **Sulfur Dioxides:-**

Sulfur dioxide (SO<sub>2</sub>) emissions in cement manufacturing are primarily associated with the content of volatile or reactive sulfur in the raw materials and in fuels <sup>[12]</sup>. The following prevention and control techniques are recommended

- Use of wet or dry scrubbers. <sup>[13]</sup>
- Selection of fuel source and quarried materials with lower sulfur content<sup>[14]</sup>
- Injection of absorbents such as hydrated lime (Ca(OH)<sub>2</sub>) bicarbonate, calcium oxide (CaO), or fly ashes with high CaO content into the exhaust gas before filters. <sup>[14]</sup>
- Use of a vertical mill and gases passing through the mill to recover energy and to reduce the sulfur content in the gas. <sup>[15]</sup>
- In the mill, the gas containing sulfur oxide mixes with the calcium carbonate (CaCO<sub>3</sub>) of the raw meal and produces calcium sulfate (gypsum). <sup>[16]</sup>

### **Particulate matter**

In cement industry emission of particulate matter (PM) is among the most major impacts of cement manufacturing <sup>[16]</sup>. PM emissions are associated with intermediate and final materials usage (crushing and grinding of raw materials) and storage, usage and storage of solid fuel, moving of materials), and packaging activities. The pollution prevention and control techniques recommended for these include the following:

- Minimizing the number of transfer point by using a simple, linear layout for materials handling operations including enclosed belt conveyors and emission controls at transfer points<sup>[5]</sup>
- Better storage raw materials and fuel. Which include storing crushed and pre-blended raw materials in covered or closed bays and storing pulverized coal and petroleum coke in silos
- Waste-derived fuels should be stored in areas which are protected from wind and other weather elements.
- Clinker should be stored in covered / closed bays or silos where dust can be extracted automatically.
- Storage of fine grades of hydrated lime should be stored in sealed silos while the storage of screened sizes of burnt lime should be in bunkers or silos.
- Material handling should be conducted in enclosed systems where pressure is maintained as negative by exhaust fans and collecting ventilation air and dust is removed using cyclones and bag filters <sup>[1]</sup>.
- To control fugitive emission automatic bag filling should be implemented by using a rotary bag filling machine.
- For transporting bags to a palletizing machine using conveyor belts and storing the finished pallets in covered bays for subsequent transport.

For particulate matter emissions which are associated with the procedure of kiln systems, clinker coolers, and mills, including clinker and limestone burning, the following pollution prevention and control techniques are recommended:

- Capturing Using filters, kiln and cooler dusts can be captured and recovered particulates can be recycled into the kiln feed and into the clinker<sup>[15]</sup>.
- To collect and control fine particulate emissions in kiln gases, electrostatic precipitators (ESPs) or fabric filter systems (bag-houses) can be used<sup>[17] [9]</sup>.
- Use of cyclones to remove large particulates of cooler gases, followed by fabric filter and filters and recycling within the mill<sup>[18]</sup>

### **Greenhouse gases:-**

Combustion of fuel and de-carbonation of limestone produces greenhouse gas emissions especially CO<sub>2</sub><sup>[20]</sup>. Control measures or techniques for emission of greenhouse gases are as follows:

- Economical fuel consumption cement production like blended cement, as less fuel emits less gas per ton of final product.
- Energy efficient process selection and operation like dry or pre-heater or pre-calciner.
- Low ratio carbon content to calorific value fuel selection like natural gas, fuel oil etc.
- Use of low organic matter content fuel.

Contribution of carbon mono oxide is only .5-1% of green house gas emission<sup>[21]</sup> whereas majority attained by emission by organic matter.

### **Heavy Metals and Other Air Pollutants:-**

Raw material, fossil fuel and waste fuel cause significant emission of heavy metal such as lead, cadmium, mercury etc<sup>[22]</sup>. Raw material and waste fuel can generate volatile metal (Mercury), which are not possible to control using filters only on the other hand nonvolatile metals are mostly bound to the particulate matter. Recommended techniques to control emission of heavy metals are:

- Activated carbon for absorption of heavy metals and efficient dust / PM abatement to capture bound metals should be used [23]. Treated material should be managed as a hazardous.
- Monitoring of combustion material i.e. composition, structure, properties control emission by using measures accordingly.
- Avoid emergency shutoffs of the electrostatic precipitators.
- Prevent usage of waste fuel during startup or shutdown

### **Fuels:-**

Pulverized coal mainly black coal and lignite are the most commonly used fuel in the cement industry but petroleum coke (pet-coke) is preferred because it is more economical<sup>[24]</sup>. Both generate higher

emissions of greenhouse gases (GHG) than fuel oil and natural gas (~ 65 percent higher emissions than with gas). Main problem with high sulfur contents in the fuel is that it buildup on the rings in the kiln. Nowadays waste fuel as an alternative however related air emission concerns, as discussed above, should be considered.

For firing waste fuels proper monitoring should be done and employment of pollution abatement measures to ensure that no toxic emissions are generated from the firing of waste in cements kilns.

### **Waste fuels:-**

Cement kilns, due to their strongly alkaline atmospheres and high flame temperatures (2000°C), are capable of using high calorific value waste fuels<sup>[25]</sup> (e.g. used solvents, waste oil, used tires, waste plastics, and organic chemical waste including polychlorinated biphenyls [PCBs], obsolete organo-chlorine pesticides, and other chlorinated materials).. If they are not controlled it can led to emissions of volatile organic compounds (VOCs), polychlorinated d-ibenzodioxins (PCDDs) and dibenzofurans (PCDFs), hydrogen fluoride (HF), hydrogen chloride (HCl), and toxic metals and their compounds

Specific permit from the local authority (SPCB) is required for the use of waste fuel or waste raw material in the cement industry. The permit should specify the amounts and types of waste that may be used either as fuel or as raw material, and it should also include quality standards such as minimum calorific value and maximum concentration levels of specific pollutants, such as PCB, chlorine, PAH, mercury, and other heavy metals. The following prevention and control techniques are recommended

- For testament of hazardous waste material and nonvolatile heavy metals PM abatement techniques should be emptied
- Rather than secondary burners, add injecting fuels directly into the main burner [26].
- Fuels that have low content of halogens during secondary firing and during startup and shutdown phases;
- To avoid or minimize the reformation of already destroyed PCDDs and PCDFs keep gas cooling time to a minimum [27].
- Use those practices that are described in the General EHS for handling hazardous and non hazardous waste.

### **Co-processing of solid waste in cement industries**

With a GDP growth rate of greater than 8%, India is the second fastest growing major economy in the world and on the track of becoming an economic giant. Due to the rise in the economy and increased industrial growth, the management of wastes generated, is presenting a very severe threat to the

society from the health, safety and environmental point of view. As per the official records, the generation rate of hazardous wastes in the country is estimated to be about 8 million tons per annum and that of the municipal solid waste (MSW) is about 40 million tons per annum.<sup>[28]</sup> Agricultural activities and industries also generate numerous non-hazardous wastes. Use of waste materials in industrial processes as alternative fuels and raw materials (AFR) to recover energy and material from them is referred as Co-processing. The high temperature and long residence time in cement kiln helps in disposing all types of wastes effectively without any harmful emissions<sup>[29]</sup>. In Co-processing emission are reduced and there is no residue after the treatment, which makes it more environmentally friendly and sustainable method of waste disposal in comparison to land filling and incineration.<sup>[30]</sup>

### **Wastewater and Industrial Process Wastewater Treatment:-**

In cement industries water is used only for cooling operation of manufacturing process. Process wastewater with high pH and suspended solids may be generated in some operations<sup>[37]</sup>. Generally water used for cooling purpose is recycled and reused in the process. Screening and for suspended solid reduction is done by using settling basin and clarifier. Water treated from waste water treatment plant should use for green belt development<sup>[38]</sup>. This green belt also helps in minimizing noise pollution.

At lime mining site and cement plant contaminated streams of rain water should be directed to the waste water treatment plant and should use for industrial process. Storm-water flowing through pet-coke, coal, and waste material stockpiles exposed to the open air may become contaminated. Rain water should be protected from contacting from coal depot clinker and lime and fly ash storage area to prevent contamination by covering the storage area and should collect at some tank for further use in dust suppression system at plant. If storm-water does contact storage yard than it may indicate presence of high value of sulphate in soil and toxic metals like Zinc, Lead and Chromium in the dust and high TDS value in ground water<sup>[39]</sup>.

### **Solid Wastes:-**

In cement manufacturing mainly solid waste include clinker production and spoil rocks, which are removed from the raw materials during the raw meal preparation. Kiln dust and fly ash from power plant also included in solid waste. Other waste is generated from plant maintenance like used oil and metal scrap. Mostly these wastes are disposed by landfill in open air which cause several lung and inhale problem<sup>[40]</sup>. Now most of the plants using fly ash for cement production. Lime waste from crushing department may be used in clinker production or sulphate treatment after re-crushing. Sometimes extensive mining activities touch the water table and may contaminate ground water. Deposit of dust in open area cause land degradation and also deposits over plant leaves. Now most of the plants using fly ash for cement production. Dust collected from different air pollution controlling devices is reused in manufacturing process<sup>[41]</sup>.



## Air Pollution Control Devices

Initially in cement industries the exhaust gas was emitted to the atmosphere without reduction treatment. Later installed Electrostatic Precipitator and Bag Filter were used to reduce gases emission<sup>[31]</sup>. Now a day's BFs and ESP are used for gases emission reductions which have high de-dusting efficiency during normal condition.

BF's as filtering which can be of woven or felted cotton, synthetic or glass-fiber in tube or envelope shape which allows passage of gases and arrest dust particle which can be collected at the bottom. Pressure drop over the filter will be very high which cause high power consumption. Special surface treatment or cleaning method (acoustic horns) can be implanted to reduce pressure drop<sup>[32]</sup>. Bags have a limited life and due to the growth of pinholes, tearing of bag or breaking of seal at fixing point cause high emission<sup>[33]</sup>. Conditioning of the exhaust gas is essential as hot particles can cause disastrous failure. Today larger size BFs are used for dedusting which increases the size and cost of the filter but allows on-line maintenance. The main advantage of bag filters is during particular conditions like high CO concentration, kiln start up; kiln shut down the de-dusting efficiency of BFs remains unchanged while the efficiency of other Air pollution control device will be decreased. If proper maintenance is provided and filter bags are replaced from time to time than Bag Filters will give high emission control. Cost for high efficient dedusting is lowest for the bag filters. Pulse jet BF and Reverse gas BF both have very similar dedusting but have different cleaning method for the bag.

In reverse gas bag filter auxiliary fan provides clean gas back to the bag for dust cake removal which are collected into the hopper. In pulse jet bag filter cleaning is done by pulsing compressed air down into each filter bag. Metal rings are provided for support of filter bags<sup>[34]</sup>.

In electrostatic precipitator electrostatic forces are used for separation of the dust from the gases. Due to high negative voltage Discharge electrode provides electrons which settle on dust particle. These particles separate on collecting electrodes because of the electric field between discharge and collecting electrode<sup>[35]</sup>. Accumulated dust is collected in the hopper by electrode rapping. These rapping can be done by sonic wave also if surface treatment is done by acoustic horns.

Pressure drop over the ESP is low and required less power consumption. It can separate both coarser and finer particle and provide a constant pressure drop which result in high cement yield. Its maintenance is easy but online maintenance is not possible. During CO peaks and kiln start up and shut down efficiency of EPS can be reduced. Efficiency of ESP can be increased by better exhaust gas conditioning and modernized control system. Cost per ton de-dusting of clinker is usually is profitable in case of ESP if final dust concentration in stack emission is high. At higher dedusting efficiency power consumption and cost increases exponentially.

To reduce very high SO<sub>2</sub> emission Circulating Fluidized Bed Absorber (CFBA) or wet scrubbers are used in the plant<sup>[36]</sup>. Selective Catalyst Reduction is used to control emission of NO<sub>x</sub>. Adsorption of Heavy metal, VOC, SO<sub>2</sub> and NO<sub>x</sub> can be done on Activated Coke, POLVITEC (AAC)

**Conclusion:** - Cement manufacturing Industries is one of the important sectors of the Indian Economy. Cement industries comes under red category as per CPCB norms. Effluent from cement

industries causing various kind of pollution (air, water and solid waste) should be treated effectively to reduce the pollution. Reuse of waste material and co-processing of solid waste in cement kiln will help in minimizing waste material.

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