Cement and its effect to the environment: A case study in SriLanka

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Abstract

Cement is an extensively used material in Srilanka. In Srilanka, the demand for cement is high both in building and infrastructure development. However, the environmental impact of cement production process starting from preproduction stages is significant. This study scrutinizes the environmental impact due to cement production process in Srilanka. A case study of Puttalam Cement Company Ltd, (the only cement production facility that encompasses the entire production process) revealed that the production adopted the dry process, which includes supply of raw materials, clinker burning and grinding process. Further the study showed that, 4-5% dust emission is due to the kiln feed, while the other sources of dust emissions include the crushers, grinding clinker coolers and material handling equipments. The case study suggests that the major sources of CO_2 emissions are from the fuel burning and during the clinker production in kiln, which forms a part of the cement production process itself. The study found that 0.613 ton of CO_2 is emitted when one ton of clinker's produced.

Keywords: Cement, Srilanka, sustainability

1. Introduction

In Sri Lanka, cement industry was introduced four decades ago by the state and managed by the state until very recently. Sri Lanka is perhaps the only country in this region, which uses 100% dry process for manufacturing cement (Mohanty, 1997). Puttalam Cement Company Ltd is the only factory that involves cement production from raw material excavation to cement packing in Sri Lanka.

The use of cement has long been the basis for development of society and for the welfare of the people for generations. Concrete, which is made from cement, has been the ultimate material for construction. Cement manufacturing process is technology intensive. Raw material extraction causes serious environmental problems by damaging the landscape and most of these raw materials become scarce. The cement industry recognizes its responsibility to manage the environmental impact, associated with the manufacturing of its product. Mainly, there are two types of cement production process; such as wet process and dry process. The preparation of cement includes mining, crushing, and grinding of raw materials, calcining the materials in rotary kiln, cooling, resultant clinker, mixing the clinker with gypsum and milling and bagging the finished cement. The cement production technologies in use cause extensive power consumption, gas emissions, noise pollution environmental heating and emissions of fuel (CO_2, NO_X SO_2 and CO) from the kiln and precalciner. These are the major sources of environmental pollution in the cement industry to the best possible extent.

1.1 Research aim and methodology

This paper reports the findings of a research study conducted in Srilanka to investigate the cement production process and its effect on environment. The aim of the research study is to identify the cement production process and its impact to the environment. A case study research approach has been adopted, since this better facilitates to study real life context in depth. The case study was conducted at the Puttalam Cement Company Ltd. Unstructured interviews were conducted in order to have comprehensive reasoning behind the identified environmental impacts. Comparison analysis was carried out to analyze the data gathered from case study with standard and guide lines.

2. Cement production Process

A cement production plant consists of the following three processes: Raw material process, clinker burning process and finish grinding process. The raw material process and the clinker burning process are each classified into the wet process and the dry process. The major processes involved in production are excavation of limestone crushing of limestone, preparation of other raw materials, grinding of raw materials in the raw mill, storage of raw meal in a raw mill silo, blending of limestone powder to control CaCO3 percentage, burning of raw meal to form clinker, grinding the clinker with gypsum in cement mill and storage of cement in silo packing and distribution of cement.

The specifications of raw materials used for cement productions are limestone 2470 ***(ton/day),*** laterite 130 (ton/day), raw meal (ground raw materials) of approximately 2600 ton/day that are passed through the kiln towards the firing end where heat is applied with heavy furnace oil. Temperature generated from burning oil is raised in the raw meal up to about 1450 °c in order to form the clinker at the rate of 1500 *ton/* day. The kiln feed is prepared by proportioning, grinding and blending the raw material into a consistent and homogeneous composition so that, after mild heating CO_2 and water could be taken away. The raw materials are processed at very high temperature so that they can react by solid-solid reactions to form clinker. These final products determine the cement characteristics such as hardening time, the early strength and the final strength. The largest volume of raw material needed is CaCO3 or comparable materials such as oyster shells (in locations where appropriate). The CaCO3 is often mined in chunks up to a diameter of 750mm. These must be crushed to about 10mm, and then mixed with sand, shale, and other ingredients for further grinding. Grinding and reactions of raw materials such as limestone (97%-96%) and laterite (3%- 4%) takes place under controlled conditions in order to produce clinker. After grinding, depending upon the exact process, water may be added. The mixture is then taken to some high – temperature processing unit, known as rotary kiln for conversion to cement clinker. The clinker must be cooled before further processing. Then it is ground in the plant with gypsum and other possible additives to a fine powder of finished cement.

2.1 Raw material for cement

Minerals of natural origin as well as industrial products can be used for the production of cement. Starting materials for this purpose are mineral compounds, containing the main components of cement, lime, silica, alumina, and iron oxide. The two main components are generally limestone and clay. In cement raw materials. The lime component is generally represented by an amount of 76-80%. Limestone is of a predominantly fine-grained crystalline structure which influences its colour. The main component of clays is formed by hydrous aluminium silicates. Clays are divided into the following mineral groups; Kaolin group (Kaolinite Dickite Nacrite Halloysite) and Montmorillonite group (Montmorillonite, Deidellite, Nontronite, Saponite) (Watter 1977). Chalk is sedimentary rock, which is formed during the cretaceous period in geological time. Blasting is not required for quarrying chalk and the crushing process can also be omitted. This kind of raw material considerably lowers the cement production costs. Calcium carbonate ($CaCO_3$) which is wide spread in nature of all geological formations qualifies for the production of cement. The most common forms of Calcium carbonate is very similar to marble, limestone and chalk.

2.2 Production process

There are four basic types of cement kiln processes currently in use. They are wet process, semi wet process, semi dry process and dry process. The kiln can be considered as the heart of the plant as it constitutes clearly the most important step in the process of cement manufacturing. Out of these, the dry process is the most energy efficient and most commonly used technology nowadays. But these process are selected with due consideration given to the properties of raw materials, cost of fuel, condition of location and others. For the wet process, plant construction cost is rather low and high quality products are manufactured easily. On the other hand, dry process consumes less energy and its running cost is lower. The progress of technology is, however, eliminating the differences in quality between products from the above processes.

Cement is produced by heating calcium (usually limestone) silica, alumina (typically clay or shale) and iron (steel mill scale or iron ore) in cement kilns. The cement burning process (preheater) is rapidly changed and accordingly the heat consumption rate is remarkably improved. Preheater tower is the heat exchanger where the heat of kiln exit gas is transferred to the incoming material (Kiln feed). Regardless of the type, the clinker cooler is installed to improve the product quality by quenching the clinker. For drying and grinding of coal and feeding to the kiln systems such as direct firing, semi-direct firing and indirect firing are used. Generally, cement’s initial strength is enhanced by improving the fineness of the product but the long-term strength is not enhanced. Therefore, excessive fine grinding should be avoided even to prevent waste of power. In cement production technologies, the recently spread roller mill makes a great contribution to the reduction of power consumption in this process.

3. Case study of puttalm cement company ltd

3.1 Introduction of Puttalam Cement Company Ltd

At present, there are two clinker grinding factories; puttalam and Kankasanturai cement factories. But Kankasanturai cement factory is not functioning for the last two decades due to the war in the north. Puttalam Cement Company Ltd is the only remaining clinker production company in Sri Lanka. Here, the clinkers are mainly obtained from Mitsui Cement and Mahaweli Marine. From the time of commissioning, for about three decades this plant was managed by a government corporation and was transferred to the pvt sector. Holcim (Lanka) with its Swiss parent company Holcim Ltd, brought worldwide experience to the Sri Lankan market, through technical and manufacturing excellence, plus a long-term commitment to Sri Lanka. Holcim Ltd focuses on long-term benefit and wishes to facilitate and be a part of the development process of SriLanka. Holcim (Lanka) Ltd operates its only fully integrated cement plant in Sri Lanka in Puttalam. It also operates a cement grinding station in Galle. The company's premium brand manufactured at Puttalam remains the only cement available in Sri Lanka that is made from local raw materials with technological know-how from one of the world's leading cement manufacturers. Its mission is to assist the growth of Sri Lanka's building and construction industry, through a long-term commitment to product quality and service excellence. These products conform to SLS 107 certification and ISO 9002 quality system.

Holcim (Lanka) Ltd continues to promote various environmental performance initiatives in its own facilities viz; reduce dust emission, create a healthy natural environment plantation, and also reduced electricity consumption. It also recognizes the importance of social responsibility as a part of its overall commitment to sustainable development. Therein, perform the following activities: maintain a community mini-hospital to provide medical services, receive proposals from premium dealers and local communities, shortlist and finalize awards to recipients, donations, press releases, workers' provident fund, community training, promote education and development.

The Putalum plant consists of several units from limestone crushers to packing plants. There are two lines of process called stage 1 & 2 each having separate processing facilities. The main processing units are crushers unit, raw mill, homogenizing plant, kiln system, cement mill and packing plant. Here, dry production process is used because energy consumption is less and running cost is also lower compared to other process. The raw materials used are in the following compositions; limestone 95-97% and laterite 3-5%.

3.2 Environmental effect due to cement manufacturing process

Emissions to air is the main environmental challenge faced by the cement industry. Main pollutions of cement productions include; cement dust, air pollution, water pollution, solid waste pollution noise pollution, ground vibration and resources depletion due to raw material extraction. Gases from the kiln and preheat are combined and used to dry and preheat the raw materials. Fuel gases consist of the components such as CO_2, N2, 02, S02, water vapor and micro components i.e. CO and NOx formation. Gases are emitted in two stages; (a) Calcinations: In high temperature, CO_2 will be released with water vapor during the CaO formation. (b) Fuel combustion: Successful operation of a rotary kiln requires an adequate source of heat that will first rise to the desired operating temperature, and then will maintain this temperature. The requirement of heat is obtained by the combustion of fuel, with a chemical reaction in which carbon, hydrogen, sulfur and nitrogen in the fuel mixes with Oxygen in the air. Dust emission is a significant source of environmental pollution during cement production.

Sources of diffused emission of particulate matters are identified in PCCL Cement. Blasting takes place at low frequency in the Arruwakkadu quarry site. The suction system of the crusher is unable to control this emission. Due to the influence of the wind, dust formation occurs at raw material storage (open yard) because of the low moisture content of the raw materials. Lots of dust is generated during the transport, loading and unloading of clinker for storage outside the silo.

3.3 Other Environments Impacts

In order to overcome deforestation, the PCCL Plant Company has a re-forestation scheme. Aruwakkadu site consists of large open space with forest. Destruction of forests depends on the quarry located. In quarry site, noise pollution is a problem due to the high noise level caused by blasting.

3.4 Gases emissions calculation

Table 1 shows, CO_2 emission per annum in PCCL plant over the period of 1990-2001 due to calcination. The below table was based on the calculation done based on the Puttalam Cement Company Limited plant report, 2001.

Table 1 CO_2 emission per annum

Year	Clinker production (tons)	Emission Factor	CO2 Production (tons)
1990	382370	0.613	234392.81
1991	398875	0.613	244510.38
1992	408925	0.613	250671.03
1993	423455	0.613	259577.92
1994	415380	0.613	254627.94
1995	403210	0.613	247167.73
1996	439190	0.613	269223.4 7
1997	453335	0.613	277894.36
1998	448505	0.613	274933.57
1999	378358	0.613	231933.45
2000	378286	0.613	231889.32
2001	379200	0.613	232449.60

The following emissions takes place in the cement production process; CO_2 emission, water vapour, SO_2 emission and NOx emission: NOx is formed from the reactions between nitrogen and oxygen in the air during combustion. According to the PCCl plant report the amount of NOx emission from cement kiln is around 200ppm (part per million), carbon monoxide (CO) is emitted in a very small quantity (approximately 0.05%) and carbon monoxide (CO) is emitted during the fuel combustion.

3.5 Particulate Pollution Abatement

One major pollution abatement method is through the use of dust collection system in various sections of cement process in PCCL plant such as cyclone separators, electrostatic precipitators (ESP), bag filters for removal and recycling arrangements for dust, except the crushers sections. During the maintenance of this equipment dust is discharged into the atmosphere without any control. However no stand-by units are available.

Dust collecting devices with the physical characteristics such as total dust load, particle size distribution, bulk density, electrical resistivity and gas volume determines the selection of suitable and efficient collection system. Some of these characteristics limit power input and collection efficiency. Dedusting equipment is in the form of bag filtering and cyclone separators. Cyclone separators (mechanical precipitation) utilize a centrifugal force generated by a spinning gas stream to separate the particulate matter from the carrier gas. It can be used at high temperatures and is suitable where coarse particles are present. Particles are removed from kiln gases by electrostatic precipitators or fabric bag collectors, either of which may be installed after the cyclone collectors. Scrubbers have had very little applications because of the problems in handling particles, which react with water. The bag filter system is one of the efficient dedusting units used in the cement industry. The filter medium is in the form of a woven textile fabric, which is arranged as tube on a suitable framework. In the course of operation, filtration efficiency will be low until a loose "floc" builds up on the fabric surface and it is this, which provides the effective filter for the removal of the fine particles. The cloth will require cleaning from time to time, to avoid excessive build up of solids, which gives room for high pressure drop. By giving knocks in regular intervals the cloth is cleaned. The Electro static precipitator has number of passages through which the gases pass. The passages are formed by two parallel rows of vertically mounted collecting plates and a number of discharges electrodes vertically suspended between the collecting plates. The high negative voltage applied discharges electrodes which creates a strong electric field between the discharge electrodes and the dust collecting plates. This produces large amount of gas ions and the positive ions being immediately attracted to the discharge electrodes, while the negative ions go towards the collecting plates. Due to these ions, dust particles are also charged. Through the influence of the electrical field, charged particles migrate towards the collecting plates. The temperature of the incoming gas stream and the voltage fluctuations greatly affect the efficiency of the extinguishers in E.S.P.

3.6 Comparisons with standards guidelines:

A comparison of the cement industries in Sri Lanka and WorId Bank group emission guidelines has been done to point out the major gaseous pollution and to improve potential application of energy efficient and environmentally sound technologies. Cement production technology based on the dry process compared to wet process is more energy efficient while it keeps running cost to a minimum. Gas emissions through kiln stack are nitrogen oxide, carbon dioxide, sulfur dioxide and carbon monoxide. Sulfur dioxide emissions are best controlled by the use of fuels. Findings show that 300mg/Nm^3 of SO_2 are stacked through due to fuel combustion. 90% of sulfur dioxide is absorbed in high alkaline condition. PCCL especially uses furnace oil which consists of low sulfur. NOx emission should be controlled by the use of proper kiln design, low NOx burners and use of optimum level of excess air. In this case, NOx emissions are 287mg/Nm^3 from the kiln stack. However the, World Bank allows maximum of NOx emissions to 600mg/ Nm3. In PCCL, the introduction of new technology of the suspension preheater kiln maintains the optimum level of excess air.

In this case, CO emission is 720mg/Nm3 from the stack kiln. However, the amount of CO emissions depends on the burner. Because, CO becomes as CO2 in high temperature. The study also found that 0.613 *t/ton* of CO_2 is emitted from the cement production process which is higher than the amount given by the standards *(0.507t1ton).* However CO_2 emission depends on the quality of raw materials and the quantity of fuel combustion. He study found that, 14-15% of green house gases are emitted into the atmosphere out of the total gases emitted from the fuel consumption in PCCL plant.

Particulate emissions are major pollution in cement industry. Here, the dust emission in a cement plant is due to improper maintenance and operation. But, all mills are provided with electro static precipitators (ESP) and bag house filters to remove and recycle dust except crusher in PCCL plant. The study revealed that, the dust emissions are approximately 52g/Nm^3 in kiln stack. World Bank standards allows maximum of 50mg/Nm3 for particulates in stack gases under full load conditions. However, the use of electro static precipitators on kilns has not been very successful in controlling pollution. Discharge of large quantities of dust into surrounding has caused drop in crop yield in nearby coconut plants and cause damage to other trees by settlement on the leaves.

3.7 Suggestions for production improvement

In this case, dust emissions can be reduced by proper maintenance of bag house filter. A schedule for maintenance should be prepared. In house dust emission measurement i.e. intensive monitoring of bag house filters should be carried out to gain more information about its effectiveness. Properly designed and operated ESP can reduce dust emission to as low as 25g/Nm3.The efficiency of ESP can be improved by decreasing the actual gas flow through ESP. It will have a positive effect on the dust collection. The reduction of the intake air leakage and a motor control system of fans will allow a better control of the flue gas flow. When the installed CO analyzer is taken out for maintenance, ESP is switched off to prevent explosion, which can occur due to high concentration of CO. CO measuring equipment should be installed in the stack of ESP, which can be connected to the sampling point of the CO analyzer after the preheater.

4. Conclusions

The cement production process consists of three processes; raw material process, clinker burning process and finish grinding process. The raw material process and clinker burning process are classified into wet process and the dry process consumes les energy while keeping running cost to its minimum. The processes are selected with consideration given to the properties of raw materials, costs of fuel, conditions of location and other factors.

Cement production is one of the main pollution contributors due to its extensive energy consumption and gas emission. Dust emission from kiln feed is 4-5%. Other sources of dust emissions include the crushers, grinding clinker coolers and material handling equipment. The priority in the cement industry is to minimize the mass load emitted from the stacks. According to the observation of study, PCCL dust collection system such as cyclone separators, electro static precipitators and bag house filters for removed and recycling arrangement is made for dust. But no standby units are available. So, during the maintenance of this equipment, dust is discharged into the atmosphere without any control. In this case, two significant types of control problems can encounter; automatic shut-off of systems related to plant, power failures leading to the emission of particulates to a higher level for shorter period of time and gradual decrease in the removed efficiency of the system over time because of poor maintenance or improper operation. Green house gases are produced directly from fuel consumption and additional cement production process itself releases carbon dioxide when the calcium carbonate in lime stone is converted to calcium oxide during the production of clinker in kiln. Also, 0.613 ton of CO_2 emission from one ton of clinker is produced.

In this case, NOx produced due to combustion of fuel. Based on calculation, the NOx emission is 287mg/Nm3. NOx should be controlled by adjustment of the kiln burner and use of an optimum level of excess air. Sulfur- dioxide emissions are best controlled by use of low sulfur fuels. In PCCL, the use of fuel consists of low sulfur concentrations. $S0_2$ emissions are 300mg/Nm^3, where 90% of $S0_2$ is absorbed by clinker in highly alkaline condition. In PCCL, the use of water is limited because the process is based on dry process. Through observation it was found that the water is used at its minimum, because the use of water for cooling purposes and water spray for dust is controlled.

The PCCL plant is situated in large area. In the surrounding there is no public living therefore, noise emission has not caused a big problem to people. With blasting at quarry site, the intensity of the vibration emission can, to some extent be controlled by the technique employed (number and spacing of blast holes, amount of explosive fired, depth of holes). Considering the energy consumption, the process of cement manufacturing process consumes two types of energy. According to observation, earlier the factory used large amount heavy furnace oil as a thermal energy. But, by changing to furnace oil, the cost of production could be reduced slightly and the gradual reduction of specific energy consumption is due to the introduction of 4- stages of suspension preheaer at factory. According to Holcim progress report June 2002 consumption of heavy furnace oil rate is 3.095t/h.

The industry can take range of steps to reduce its green house gases emissions. Introduction of Greenhouse Energy Management System (GEMS), which is based on the green gas monitoring and evaluation has streamed- lined identification of options for reducing greenhouse gas emissions, reduce thermal energy consumption, minimize dust by proper maintenance of bag house filters and ESP, optimizing of electro static precipitators and water sprayer at site to installation of complex pollution control equipment. The industry can take measures to reduce its green house gases through some kind of plantation in surrounding.

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