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EMISSION ESTIMATION OF AIR POLLUTANTS AND ITS CONTROL TECHNIQUES AT CEMENT MANUFACTURING FACTORY IN KHULNA

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ABSTRACT

Cement industry is one of the most causative anthropogenic sources involved in air pollution and the typical gaseous emission to air from it include nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon oxides (CO and CO_2), particulate matter and some trace quantities of volatile organic compounds. This study has determined the sources of air pollutants with availing field survey at a cement manufacturing factory (CMF) near Rupsha River (sampled area) in Khulna city. 'Emission factor' method from Emission Estimation Techniques (EETs) manual for cement manufacturing accredited by EPA, Australia has been adopted to estimate the annual emission of air pollutants by weight. At CMF the emission of air pollutants has been found approximately 385.767 metric ton/year which indicates 0.297 kg per ton of cement production. It has been observed that the emission of air pollutants from sampled CMF is comparatively lower than other CMF as the clinker and other additives are being imported here. But to ensure a complete healthy environment at CMF the necessary strategies have been suggested in this study for reducing the gap between standard level and current situation and to enhance the improvement of air quality management at CMF.

Key Words: *Cement manufacturing factory, Anthropogenic sources, Air pollutants, Emission Estimation Techniques (EET) manual, Air quality management.*

1. INTRODUCTION

Air is the basic necessity of human life but the quality of air is deteriorating continuously and it is being constantly polluted from different sources (Mehraj & Bhat, 2013). World Health Organization (WHO) reports that in 2012 around 7 million people died (one in eight of total global deaths) as a result of air pollution exposure [WHO, 2012]. The finding also confirms that air pollution is now the world's largest single environmental health risk. Several studies reported significant correlations between air pollution and certain diseases including shortness of breath, sore throat, chest pain, nausea, asthma, bronchitis and lung cancer (Dockery and Pope, 1994, U.S. EPA 1999a; U.S. EPA 1999b; Jeff and Hans 2004). In addition to its destructive health impacts, air pollution is also catastrophic to animals, forests and vegetation, aquatic ecosystems, metals, structures etc. So, reducing air pollution is mandatory to protect the environment. Cement industry is one of the most causative anthropogenic sources involved in air pollution and it has been listed in seventeen most polluting industries by the central pollution control board.

Cement is one of the most essential items for infrastructure development and civil construction works. It is a fine powder consisting predominantly of calcium silicates, aluminates, alumino-ferrites and, to a lesser degree, gypsum and some cementious materials. In cement manufacturing process most of the raw materials (lime, silica, alumina, and iron) are extracted from the earth through mining and quarrying. Then extracted raw materials are mixed to obtain the correct chemical configuration, and grind to achieve the proper particle-size. In pyro-processing, the grinded raw materials are heated into rotary kiln to form cement clinkers. The fuel to be used for this purpose can be coal, oil or gas. Clinkers are hard, dark grey, vitrified glassy nodules with varying size of 0.32 - 5.0cm created from the chemical reactions between the raw materials. The clinker after being cooled is ground sometimes with different additives like gypsum, slag, fly ash etc. to obtain a fine powdery state. The finished product is cement which is delivered to customers in bags normally having 50kg weight.

Modern life without cement is impossible to conceive (Potgieter 2012). Despite its lucrativeness it confronts many challenges due to environmental concerns and sustainability issues. The typical emissions to air from cement manufacturing plants include nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon oxides (CO and CO_2) and dust. Nitrogen oxides release from combustion of fuel at high temperature in the cement kiln. Three types of NOx form in the cement kiln- thermal, fuel, and feed NO_X. In kiln exhaust gases, more than 90% of NOx is NO, with NO_2 generally making up the remainder (Nielsen and Jepsen, 1990).At high concentrations NOx has a pungent odor and can cause eye, nose and throat irritation, respiratory illness such as asthma and can also contribute to the formation of photochemical smog. NOx reduction techniques for cement kilns are classified in two broad categories, process controls and post-combustion controls. Process controls, including combustion modifications, rely on reducing or inhibiting the formation of NOx in the manufacturing process. Post-combustion controls rely on treatment of the flue gases to remove NOx that has already been produced. Alternative or low-nitrogen fuels can also reduce emission of NOx.

Sulfur oxides, mainly SO_2, are generated both from the sulfur compounds in the raw materials and from sulfur in fuels used to fire a preheater/precalciner kiln system. SO_2 is both liberated and absorbed throughout the pyroprocessing system, starting at the raw mill, continuing through the preheating/precalcining and burning zones, and ending with clinker production. SO_2 can react with other compounds in the air to form small particles which penetrate deeply into sensitive part of the lungs and can cause the respiratory, heart diseases and premature death. The highly alkaline conditions of the kiln system can capture up to 95% of the possible emissions of SO_2. But this absorption rate may decline to as low as 50% if sulphide (pyrites) is present in the kiln feed. Therefore, careful selection of raw materials is needed to lower the sulphur oxides emissions. Also using of oil or gas fuel instead of coal fuel can contribute in considerably lowering of sulphur oxides.

It is estimated that 5-6% of all CO_2 greenhouse gases generated by human activities originates from cement production (Rodrigues & Joekes, 2010). Carbon dioxide as a by-product is released during the production of clinker in which calcium carbonate ($CaCO_3$) is heated at temperatures of 600-900°C in a rotary kiln and results in the conversion of carbonates to oxides. The simplified reaction is:

$$CaCO_3 + \text{heat} \longrightarrow CaO + CO_2$$

CO_2 is also emitted from additional lime that requires in Portland composite cement. To minimize CO_2 emissions from cement plants, three ways for improvement have been identified: (1) increasing energy efficiency in order to consume less energy, (2) using alternative fuels (e.g. biomass) to replace conventional fuels, and (3) greater use of cementious additions such as slag and fly ash.

Cement industries may emit a wide range of organic compounds include Polycyclic aromatic hydrocarbons (PAHs), polychlorinated dioxins and furans in trace quantities which depends on the nature of raw materials and fuels or the combustion efficiency of the process. Selection of material with lower organic matter content can lower organic compounds as well as CO emission.

In cement industries, heavy dust emits from quarrying, crushing, grinding and transportation of raw materials, kilns operation, clinker cooling, stock piles and packaging. Cement dust contains heavy metals like chromium, nickel, cobalt, lead and mercury pollutants hazardous to the biotic environment with impact for vegetation, human health, animal health and ecosystem (Baby et al.; 2008). Even prolonged exposure can cause serious irreversible damage to plants and animals. Other reported effects of cement dust on plants include reduced growth, reduced chlorophyll, clogged stomata in leaves, cell metabolism disruption, interrupt absorption of light and diffusion of gases, lowering starch formation, reducing fruit setting (Lerman, 1972), thus causing suppression in plants and in animals it leads to various respiratory and hematological disease, cancers, eye defects and genetic problems (Iqbal and Shafug, 2001). To control of dust from cement manufacturing operations require high cost technological solutions. But well-planned management of activities in total operation can lessen the generation of dust significantly and with relatively little additional cost. The use of covered or enclosed conveyers, crushers, material transfer points and storage areas; installation of dust collectors or Electrostatic Precipitator where needed; paved roads; vacuum sweepers for plant roads; water sprinklers for plant roads and storage piles; latex stabilizing sprays for storage piles; and site landscaping and vegetation may be the effective dust control measurement in cement industries.

Concern about air pollution in urban regions is receiving increasingly importance worldwide, especially pollution by gaseous and particulate trace metals (Begum et al., 2004). Khulna, the third largest city of Bangladesh and recently many cement manufacturing factory (CMF) are being constructed which may cause a tremendous alteration in environmental air quality. This study has determined the sources of air pollutants and scenario of existing practices of air quality management at a CMF near Rupsha River (sampled area) in Khulna city. This study has also estimated the amount of emitted air pollutants per year and suggested some mitigation strategies for reducing the gap between standard level and current situation to enhance the improvement of air quality management at CMF.

2. METHODOLOGY

- Several field surveys has been conducted to study the total mechanism of existing process of cement production at sampled CMF which helped to determine the sources of air pollutants and the existing practice of air quality management at CMF.

- 'Emission factor' method from Emission Estimation Techniques manual accredited by EPA, Australia for cement manufacturing has been adopted to estimate the annual emission of air pollutants by weight. An emission factor is a tool that is used to estimate emissions to the environment. In this manual, it relates the quantity of substances emitted from a source to some common activity associated with those emissions.

- In this study; annual emissions of particulate matter and CO_2 beyond the production of clinker has been calculated by these equations:

When bag filter outside-venting: $Ekpy,_{PM10} = EF_{PM10} * A * OpHrs * 10^{-6}$;
Where**;** $Ekpy,_{PM10}$ = annual emissions of $_{PM10}$, kg/yr
EF_{PM10} = emission factor for PM10, mg/m3, in this case $12mg/m^3$
(Where $12mg/m^3$ is 80% of the total particulate matter ($15mg/m^3$vented from the bag filter.)
A = activity rate (hourly flow of air exhausted through the bag filter), m3/hr
OpHrs= operating hours, hr/yr
10^6 = conversion factor mg to kg.

From material storage: Annual emissions; $E_{kpy,\ PM10} = E_{PM10} * OpHrs$
Where; E_{PM10} = hourly emissions of PM_{10}, kg/hr
EF_{PM10} = emission factor of PM10, kg/ha/hr
$E_{PM10} = EF_{PM10} * Area * ER_{PM10}$
Area = area of base of stockpile, ha
ER_{PM10} = emission reduction of PM_{10}, %, (see Table: 1)
NB: In the absence of available PM_{10} data use the default EF_{PM10} = 0.3 kg/ha/hr.

Table 1: Emission Reduction Factors for Materials Handling and Storage

Reduction Method	Reduction Factors (ER_{PM10})	Control Efficiency (CE_{PM10})
Wind breaks	0.7	30%
Water sprays	0.5	50%
Chemical suppression	0.2	80%
Enclosure (2 or 3 walls)	0.1	90%
Covered stockpiles	0.0	100%

- In Portland Composite Cement (PCC) requires additional lime. To account for this, the *IPCC Guidelines* provide an equation, based on masonry cement production parameters, to estimate CO_2 emissions resulting from the additional lime. The equation is illustrated below:

CO_2 (tons) from CaO added to PCC = a * (all cement productions) * ((1-1/ (1 + b)) * c) * 0.785
Where; a = fraction of all cement produced that is PCC (e.g., 0.05-0.2)
b = fraction of weight added to PCC by non-plasticizer additives such as lime, slag, and shale (e.g., 0.004, 0.006)
c = fraction of weight of non-plasticizer additives that is lime (e.g., 0.7-0.9)
a* (all cement production) = masonry cement production
((1-1/ (1+b)) * c) = fraction of lime in masonry cement not attributable to clinker
((1-1/ (1+ b)) * c) *0.785 = an emission factor of CO2 from masonry cement additives

3. ILLUSTRATIONS

3.1The sampled area.

The sampled area, Shun Shing Cement Mills Ltd (SSCML) is situated in the industrial area of Labanchara and just beside the Rupsha River in Khulna city. Among the different industries the important ones are fish processing industries, Bangladesh Oxygen Company, Khulna shipyard, Bangladesh Match Factory and Dhaka Match Factory and so on. The annual cement production of SSCML is 1.3 million metric ton and two types of cement i.e. Portland Composite Cement (PCC) & Ordinary Portland Cement (OPC) are produced here. Here only 5% gypsum is added to the 95% clinker in manufacturing OPC where as in PCC 8.5% slag, 4%limestone, 3.5% gypsum and 22% fly ash is added to 62% clinker. In SSCML, the clinker and the cementious materials are imported from different countries.

In SSCML, the clinker and the cementious materials (fly ash, gypsum, slag and limestone) are imported from foreign countries i.e. China, Vietnam, Thailand, Japan, India and South Korea. Most of the time the clinker is conveyed by a conveyor belt from jetty to roller ball mill (movable and fixed) directly for grinding without keeping in storage. But the other imported cementious materials are generally kept for storage in closed space and then they are conveyed by conveyor belt to roller ball mill according to their requirement. In the closed circuit system, grinding is carried out in the mill and the ground material (Clinker, Gypsum, Limestone and Slag) is sent to a separator for classification. The coarse material is returned into the mill and the fine material is separated out as the product resulting in a uniform particle size distribution. Then fly ash is added to the fine ground material. All the processes at different stages of operation in this cement mill are automatic. The total manufacturing process of cement production in SSCML is described in below as flow diagram:

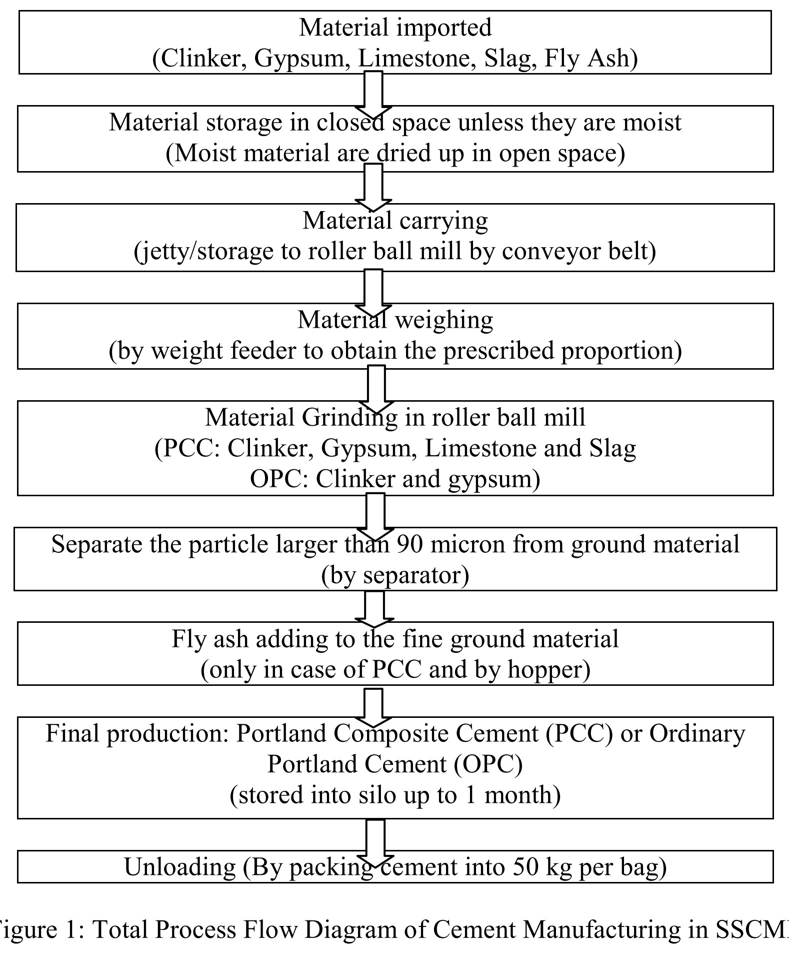

Figure 1: Total Process Flow Diagram of Cement Manufacturing in SSCML

3.2 Estimated emission of air pollutants & control management at SSCML

Emission of air pollutants from CMF is generally classified into two groups: gaseous emission and particulate emission. Gaseous emission includes emission of nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon oxides (CO and CO_2) and volatile organic matters where as particulate emission includes basically cement dust. Gaseous pollutants emit mainly during clinker production in rotary kiln and also from preheater and clinker cooler. But particulate matters emit almost throughout total process flow of cement manufacturing including quarrying, crushing, grinding and transportation of raw materials, kilns operation, clinker cooling, stock piles and packaging.

At SSCML, emission of air pollutants is comparatively low than other cement manufacturing industry as the clinker and other additives are being imported. Only a small amount of CO_2 emit through the addition of limestone in manufacturing of PCC. But a significant amount of dust is generated during the handing, storing of imported materials, transport, weighing, grinding and packaging operations of cement manufacturing process at SSCML.

(i) The emission of CO_2 due to additional lime at SSCML**:** 340.167 metric ton/year (approximately) As at SSCML,
Total production of cement: 1.3 million metric ton (annually)
Fraction of all cement produced that is PCC, a = 0.75
Fraction of weight added to PCC by non-plasticizer additives such as lime, slag, and shale, b = 0.125
Fraction of weight of non-plasticizer additives that is lime, c = 0.04

(ii)The generated amount of dust at SSCML (from material storage)**:** 0 kg/year (approximately)
The raw materials at SSCML are stored in an enclosed building. As a result according to Table: 1 the emission reduction of PM_{10} is 0 % and so that control efficiency is 100% which indicates there is no emission of particulate matter to the air due to material storage.

(iii)The generated amount of dust at SSCML (when bag filters venting outside): 45,593.21 kg/year (approximately)
*Operating hours of SSCML= 6570 hr/yr

Table 2: Estimated emission of air pollutants

System Name	No. of Bag filter	Air flow (m^3/hour)	Emission factor (mg/m^3)	Annual dust emission (kg/year)
1. Clinker silo top (bucket side)	01	4,500	12	358.78
2. Clinker silo top	03	11,160		2,639.56
3. Clinker silo bottom	03	6,900		1,631.99
4. Gypsum jetty (hopper side)	03	4,500		1,064.34
5. Gypsum jetty (belt side)	01	4,500		358.78
6. Gypsum, limestone and slag unloading point (hopper side)	01	2,000		157.68
7. Gypsum, limestone and slag unloading point (bucket side)	01	2,000		157.68
8. Gypsum, limestone and slag unloading point (belt side)	02	2,000		315.36
9. Pre feeding silo top	02	4,500		717.56
10. Fly ash silo top	01	16,200		12,777.20
11. Fly ash silo bottom	01	1584		124.88
12. Mill main outlet bag filter	02	40,000		6,307.20
13.Main mill bag filter	01	2,40,000		18,921.60
14. Cement silo (air slide)	01	3,500		275.94
15. Cement silo (top)	02	6,900		1087.99
16. Feeding belt- pre feeding silo	02	4,500		717.56
17. Bulk loading carrier	01	6,900		543.99
18. Packing (bucket side)	02	4,500		717.56
19. Packing (cement bin side)	02	4,500		717.56
			Total =	45,593.21

At SSCML the emission of CO_2 due to additional lime at SSCML is approximately 340.167 metric ton/year which means 0.262 kg per ton of cement production or 5.23 g per cement bag where as in worldwide averagely 222 kg CO_2 emits per ton of cement production. The generated amount of dust at SSCML from material storage is approximately 0 kg/year as the raw materials are stored in an enclosed building there. Also the total generated amount of dust at the point where bag filters installed at SSCML is approximately 45,593.21 kg/year or 45.60 metric ton/year which means 0.035 kg per ton of cement production or 0.70 g per cement bag. But it has been reported that 1 kg of cement manufactured in Egypt generates about 0.07 kg of dust in the atmosphere. So it indicates the air quality of SSCML is controlled in a better way.

To control the particulate matter, dust collectors are provided at every point where dust is generated in mill. Dust collectors are also provided at belt conveyor discharge points, clinker and gypsum feeding units, silo extraction, packing plant and filling points. The dust arising due to vehicular movement is prevented by paving most of the internal roads at SSCML. Also many of belt conveyors are covered with hoods to resist the trapping of material in wind stream.

Though to ensure a complete healthy environment, emissions of particulate matters from all the units of the cement plant should be fully controlled. With this consequence some actions may be taken i.e. each conveyor needs to be provided with conveyer hoods to offset any trapping of material in wind stream, the sprinkling of water should be done along the internal unpaved roads in the plant in order to control the dust and the using of mask by the employee should be encouraged at the cement plant. Also a **t**hick greenbelt can be developed around the plant to arrest the fugitive emissions.

4. CONCLUSIONS

In this study, the sources of air pollutants and their present air pollution control strategies at sampled CMF have been addressed. Also the emission of air pollutants has been quantified to understand the current air quality level there. The emission level is considerably low comparing with others as this CMF only covers the grinding operation with imported raw materials including clinker. This study recommends establishing this type of CMF more so that air quality can be maintained within reasonable range. It also suggests to Government of Bangladesh (GoB) to consider the CMF as a contributory factor for deleterious impact on environmental air quality as it has been recognized to be playing a vital role in the imbalances of the environment and producing air pollution hazards. So, it recommends to GoB to enforce the law to each CMF to take necessary steps to enhance air quality management at CMF within their limited resources.

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