HIERARCHICAL BASED INTEGRATED DUST MANAGEMENT SYSTEM IN A CEMENT MANUFACTURING PLANT IN MALAYSIA

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ABSTRACT

Cement is one of the world's most significantly manufactured materials. Being the major constituents of concrete, cement is manufactured in such huge quantities as statistics shows that, on average, approximately 1 ton of concrete is produced annually for every single person in the world. Although cement industry is widespread with high profitability, it faces many challenges due to environmental concerns and sustainability issues. The industry has a significant contribution to environment imbalances, especially air quality. This is because, in cement manufacturing process, almost every process contributes to generation of significant amount of dust. Therefore, in this study, a cement plant was chosen as a case study. The study was conducted in characterizing dust particles produced, its sources of generation and potential risk. Recommendations were made in mitigating, preventing or minimizing the dust generation using various approaches. Process flow and other data such as the mass balance, dust emissions and the dust management systems were collected from the plant. From the obtained data, characterization of dust was done. The risk assessment done on the dust generation sources revealed that the highest priority of dust management required in quarry, kiln and raw material processing which has high impact rating. This study shows that waste management hierarchy can be used as a model to manage the dust being generated in the plant. By implementing the hierarchical based integrated dust management system, the plant can save significant cost being spent on the product (cement dust) loss, damages to the equipment and frequent change of the dust control technologies. Since the production of cement is involving large area and number of processes, in future the study can be improved by focusing on one process/equipment at one time.

ABSTRAK

Simen adalah antara bahan yang paling banyak dihasilkan di seluruh dunia. Sebagai bahan utama konkrit, simen dihasilkan dalam jumlah besar. Mengikut statistik, kira-kira 1 tan konkrit dihasilkan setiap tahun untuk setiap orang secara purata. Walaupun industri simen tersebar luas dengan keuntungan yang tinggi, ia menghadapi pelbagai cabaran kerana isu alam sekitar dan masalah kemampanan. Industri ini mempunyai sumbangan penting kepada ketidakseimbangan alam sekitar, terutamanya kualiti udara. Dalam proses pembuatan simen, hampir setiap proses menyumbang kepada penjanaan debu yang banyak. Oleh itu, dalam kajian ini, sebuah kilang simen telah dipilih dan kajian dijalankan bagi mengelaskan zarah debu yang dihasilkan, sumber penjanaan dan risiko yang berpotensi daripada debu tersebut. Cadangan diberikan dalam mengurangkan, mencegah atau meminimumkan penjanaan debu menggunakan pelbagai pendekatan. Aliran proses dan data lain seperti imbangan bahan, penjanaan debu dan sistem pengurusan debu diperoleh. Dari data yang diperolehi, pencirian debu dilakukan dan risiko debu yang dijana dinilai. Penilaian risiko yang dilakukan terhadap sumber penjanaan debu menunjukkan bahawa keutamaan pengelolaan debu yang diperlukan dalam kuari, kiln dan pemprosesan bahan mentah yang mempunyai penilaian kesan yang tinggi. Kajian ini menunjukkan bahawa hierarki pengurusan sisa boleh digunakan sebagai model untuk menguruskan habuk yang dihasilkan di kilang tersebut. Dengan melaksanakan sistem pengurusan debu bersepadu berasaskan hierarki, kilang itu boleh menjimatkan kos yang besar untuk membelanjakan kerugian produk (debu simen), kerosakan kepada peralatan dan pemasangan teknologi kawalan debu yang kerap. Oleh kerana pengeluaran simen melibatkan kawasan besar dan bilangan proses pada masa akan datang, kajian dapat diperbaiki dengan memfokuskan pada satu proses / peralatan pada satu masa.

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LIST OF SYMBOLS AND ABBREVIATIONS

NO	:	Nitric oxide
NO_2	:	Nitrogen dioxide
PM	:	Particulate matter
CO	:	Carbon monoxide
SO_2	:	Sulphur dioxide
PCDD	:	Polychlorinated dibenzo-para-dioxins
PCDF	:	Polychlorinated dibenzofurans
APCD	:	Air Pollution Control Device
TPD	:	Tonnes per day
NDA	:	Non-disclosure agreement
HBIDMS	:	Hierarchical Based Integrated Dust Management System
COPD	:	Chronic Obstructive Pulmonary Disease

CHAPTER 1: INTRODUCTION

1.1 Background of Study

Cement is one of the world's most significantly manufactured materials. Being the major constituents of concrete, cement is manufactured in such huge quantities as statistics shows that, on average, approximately 1 ton of concrete is produced annually for every single person in the world. Hence, cement demand can be directly linked to economic growth where many growing economies venture for development of rapid infrastructure that requires huge amount of concrete and cement. Understanding the environmental, safety and health implications of cement manufacturing is becoming significantly important due to its growing abundance in the world market.

In this industry, industrial plant smokestacks are some of the major contributors to poor air quality, especially in urban developments. The cement industry drastically contributes to pollution of the surroundings; specifically, in terms of air quality. During cement manufacturing process, dust is emitted in significant amount at almost each stage. This dust production may result from many activities including spillage and leakage throughout cement manufacturing. The concentrations of the fugitive dust generated may differ to a great extent based on various factors such as weather and condition of the cement manufacturing plant.

To control air pollution, especially dust pollution caused by cement manufacturing process, various dust management systems are adopted in cement plants. These dust management systems may work individually or collectively, based on the severity of pollution in each process.

1.2 Problem Statement

The cement industry is growing rapidly and many cement making companies are now able to produce higher volumes of cement compared to the past due to the latest advancement in technology. However, these higher volume productions are also seen as huge contributor and the leading cause of pollution. The industry has a significant contribution to environment imbalances, especially air quality. This is because, in cement manufacturing process, almost every process contributes to generation of significant amount of dust.

These processes include spillage, leakages, transporting and raw milling which begins in raw material quarrying until the shipping of cement from the plant. The dust generated poses environmental, safety and health problems for the not only the operators but also environment. Dust generated, if not well managed will significantly contribute to air pollutions and have negative impact to community nearby as well as surrounding environment. In addition, the dust also reduces plant productivity due to damages on the processing equipment.

Therefore, in this study, a cement plant is chosen for a case study and overall study is conducted in characterizing dust particles produced, its sources of generation and potential risk. Then, recommendations can be made in mitigating, preventing or minimizing the dust generation using various approaches. The problem being addressed in this work can be represented by following research questions:

a. What are the sources, characteristic and risks from dust particles generated at a typical cement plants?
b. What are the mitigative and preventive measures and technologies that can be used to reduce minimize or prevent dust particles generation?

1.3 Aim and Objectives

The study aims to prevent dust pollution from cement factory.

To achieve the aim, the following objectives were defined:

a. To investigate sources, characteristic and possible risk of the dust generated in the chosen cement plant
b. To propose various strategies, technologies and control measure which can reduce the dust generation
c. To conduct performance and financial evaluation on the selected proposed technology.

1.4 Scope of the Study

This study was carried out in a cement manufacturing plant located in Peninsular Malaysia. The selected plant has integrated cement manufacturing facilities from raw material quarry to packaging then shipping. In order to achieve the objectives, several detailed scope as below was carried out:

a. Plant layout and process flow chart retrieval from selected premise and subsequent site visit to understand the overall process
b. Data collection from plant process department, environmental department and finally sales and marketing department.

1.5 Report Layout

This research report consists of five main chapters. The chapters are elaborated as per following:

a. Chapter 1: Introduction

This chapter covers introduction to cement, the cement industry and also the purpose or significance of the study. In this chapter, the objectives are clearly shown and the scope of the study has been defined.

b. Chapter 2: Literature Review

In this chapter, detailed information on topics related to cement, the industry, types of dust emission, regulatory practice and other general information are clearly shown. Dust pollution issues and its management system have also been discussed.

c. Chapter 3: Methodology

Relevant to the objective, methodology was constructed to be conducted in the selected cement plant. The methodology is ensured to enable identification of dust generation sources and prevention of dust generation. The methodology followed was ensured to achieve the objectives of research.

d. Chapter 4: Results and Discussion

Results obtained from the cement plant based on constructed methodology were shown in the form of tables and layouts. The results are further discussed in this section.

e. Chapter 5: Conclusion and Recommendation

Conclusions are drawn from the results obtained and presented in this section. Finally, few recommendations for future work were made to ease or improve future studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to Cement

Cement is the most important element of a concrete which act as a binder to hold concrete mixtures together firmly to form a strong building material. As defined by Macfadyen (2006), “Cement is a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties”. It plays a crucial and significant role as a basic material used in building and civil engineering throughout the human civilization and current fast pace urbanization ("Concrete: Scientific Principles", 2017). The industry has been improving living standard worldwide by creating new employment opportunity and giving various high financial benefits to associated industries. It stands out amongst the most generally utilized materials on the earth. Annually, around 3.6 billion metric tons of cement is produced worldwide, with volume anticipated to reach 5 billion metric tons by the year 2030. As developing countries require more cement for their infrastructure growth, the business is developing fast especially in these countries (Felekoglu et al., 2007). Although cement industry is widespread with high profitability, it faces many challenges due to environmental concerns and sustainability issues (Potgieter, J.,2012).

2.1.1 Basic Components of Cement

While it is critical to have the right extents of calcium, silicon, aluminum, and iron, the chemical composition and structure of the each of the raw material can differ significantly for various cement batches. Table 2.1 shows some of the raw materials or minerals that can be utilized to produce cement in plants.

Table 2.1: Examples of raw materials for portland cement manufacture (Kosmatka et al., 2002)

Calcium	Silicon	Aluminum	Iron
Marl	Marl	Shale	Iron ore
Calcite	Sand	Fly ash	Mill scale
Aragonite	Shale	Aluminum ore refuse	Shale
Shale	Fly ash		Blast furnace dust
Sea Shells	Rice hull ash		
Cement kiln dust	Slag		

At high temperature of process of manufacturing cement, the raw materials that are provided will burn and oxygen gas which is readily available in air will replace them. Portland cement has a fine texture, composed of tricalcium aluminate, tricalcium silicate and tetracalcium aluminoferrite in addition of calcium sulfate in various forms.

2.1.2 Cement Manufacturing Process

Basic manufacturing process for cement industry consists of six major phases as listed in coming sub-chapters.

2.1.2.1 Raw Material Extraction/ Quarry

The first phase is raw material preparation involving quarrying and grinding.

Figure 2.1: Extraction of raw material (Afsar, 2017)

2.1.2.2 Grinding, Proportioning And Blending

Once extracted, the raw materials from quarry are transported to plant laboratory. Here, the raw materials are analyzed and the correct ratio of limestone and clay are made possible prior to grinding process. The common proportion used is 80% wt of limestone and 20% wt of clay.

2.1.2.3 Pre-Heating Phase

Once grinding is done, the materials will be brought to pre-heating chamber which has few vertical cyclones for them to pass through. Hot gases from kiln in the next phase are used by the re-heating chamber. The pre-heating phase enables energy saving and the plant to adapt greener technologies.

2.1.2.4 Kiln Phase

In this phase, a large furnace (kiln) is the critical part. The phase involves a high temperature of 1450°C. High temperature where the materials are subjected to, creates decarbonation process, where some carbonate elements produces carbon dioxide gas, creating material slurry.

2.1.2.5 Cooling and Final Grinding

Out of the kiln, the clinkers' temperature is lowered down by using forced air. Clinker will then remove the hot air. The hot air released from clinker is recycled in kiln later.

2.1.2.6 Packing & Shipping

Once all done, the materials are taken in a conveyer to the silos where cements are stored after grinding. Then, the cements are packed into smaller packaging of around 20-40 kg bags. After packing some small amounts of cements in this packing for customer requests, remaining cement quantity stored are transported in big quantities by various transportations.

2.2 Cement Industries in Malaysia

Figure 2.2 shows the production of cement. Production of cement in Malaysia was 1137.28 thousand of tonnes in average from year 1985 until 2017. The production reached its highest peak in January 2017, at 2442 thousands of tonnes and the lowest this figure has ever reached is 147 thousands of tonnes, which was back in February 1987. Recently, from March to April 2017, production of cement in Malaysia has decreased from 1529 thousands of tonnes to 1404 thousands of tonnes.

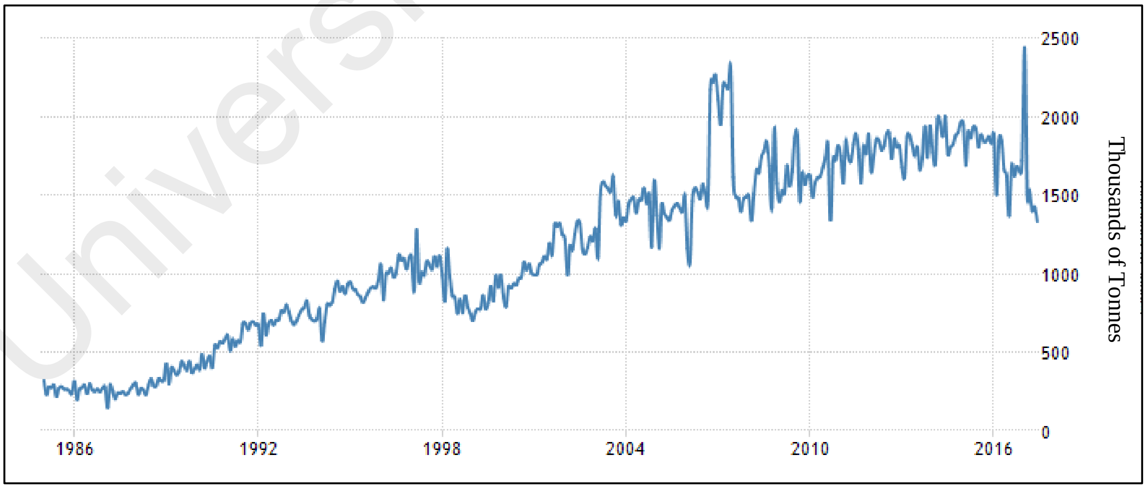

Figure 2.2: Malaysia Cement Production 1985 – 2017 (Department of Statistics Malaysia)

Cements produced in Malaysia are mostly used domestically. Singapore, which does not have any active integrated cement plants has been importing significant amount of cement. In terms of cement production capacity, Malaysia is the fifth largest producer in ASEAN country. Construction and real estate sectors are the contribution factor on the prospect of the cement industry. The 11th Malaysia Plan running from year 2016 to 2020, which strongly emphasize on urban ventures such as the development of the Klang Valley MRT, Pan-Borneo Highway, and KL-Singapore High Speed Rail projects will boost the construction sector (The Cement and Concrete, 2017).

2.3 Regulatory Requirements in Malaysia

Table 2.2 shows the Ambient Air Quality Standard 2014 in Malaysia and relevant interims. The new Environmental Quality (Clean Air) Regulations 2014 was implemented beginning of July 2014 and will be fully enforced in July 2019. It is important to note that Environmental Quality (Clean Air) Regulations 1978 is still valid until June 2019. New Ambient Air Quality Standard established six air pollutants criteria that include nitrogen dioxide (NO_2), ground level ozone (O_3), particulate matter with the size of less than 10 micron (PM10), carbon monoxide (CO), sulfur dioxide (SO_2), and also an additional parameter, particulate matter with the size of less than 2.5 micron (PM2.5).

Based on the Recommended Malaysian Air Quality Guidelines, the concentration limit of each pollutant listed are to be strengthened in several stages until year 2020. There are three interim targets set for this, which is interim target 1 (IT-1) in year 2015, interim target 2 (IT-2) in 2018 and complete implementation of the standard in year 2020.

Under the third schedule in Environmental Quality (Clean Air) Regulations 2014, cement industry is listed under non-metallic (mineral) industry: cement production (all sizes). The standard limit values of pollutants in cement industry and their relevant monitoring frequency is shown in Table 2.3.

Table 2.2: Malaysian ambient air quality standard 2014 (DOE, Malaysia)

Pollutants	Averaging Time	Ambient Air Quality Standard		
		IT-1 (2015)	IT-2 (2018)	Standard (2020)
		µg/m3	µg/m3	µg/m3
Particulate Matter with the size of less than 10 micron (PM10)	1 Year	50	45	40
	24 hours	150	120	100
Particulate Matter with the size of less than 2.5 micron (PM2.5)	1 Year	35	25	15
	24 hours	75	50	35
Sulfur Dioxide (SO2)	1 Year	350	300	250
	24 hours	105	90	80
Nitrogen Dioxide (NO2)	1 Year	320	300	280
	24 hours	75	75	70
Ground Level Ozone (O3)	1 Year	200	200	180
	24 hours	120	120	100
*Carbon Monoxide (CO)	1 Year	35	35	30
	24 hours	10	10	10

Note: *mg/m^3

Table 2.3: Standard limit values and relevant monitoring frequency (DOE, Malaysia)

Source	Pollutant	Limit Value	Monitoring
Cement kilns	Sum of NO and NO_2 expressed as NO_2	800 mg/m^3	Continuous*
	Total PM	50 mg/m^3	Continuous*
	Mercury	0.05 mg/m^3	Periodic
	PCDD/PCDF	0.1 ng TEQ/m^3	Periodic

* Averaging time for continuous monitoring is 30 minutes

2.4 Dust pollution issues

Dusts generated in cement plant are usually recycled or treated before release. However, there is still significant number of issues from the dusts being dispersed in air consequently contributing to the air pollutions. These dust emissions to the surrounding and air by cement industries can pollute the ambient air (Kabir and Madugu, 2010).

Dust pollution has garnered so much attention due to its negative effects to human health and environment. As studied by Mehraj and Bhat, there are various epidemiological studies that have shown a strong connection between increasing levels of particulate matters (PM10 and PM2.5) and higher morbidity and mortality rate. Particulate matter in the air is mainly micron and sub-micron particles resulted from human activities and natural sources. As the potential impacts of these fine particles are closely associated with their size and other parameters, characterization of these particles has now become the highest priority (Zeleke et al., 2010).

2.4.1 Sources of Dust

Dust and other fine particulates generation in cement manufacturing is unavoidable, but most of these are recovered and recycled in the process. Cement manufacturing plant generally releases dust throughout the process starting from raw material preparation until packaging of the finished product. There are two types of dust sources, point source and fugitive source. Point source or process related dust refers to the dust in air or gas flow in the system in a confined flow stream which entrains the dust in this section such as mills, kiln and clinker cooler. Reduction in generation of this dust requires examination of process parameter, material characteristic and dust load (Nazaret, 2014).

Dusts generated from open sources are called fugitive as they do not release into the atmosphere in a confined flow stream as similar to point-sources (Massacci et al., 2003). Common sources of dust emission are clinker cooler, grinders, crushers and material-handling equipment such as conveyors result in fugitive dust emission (Cheremisinoff, 2001). Potential sources of dust collection in cement plants are during the delivery of raw materials in trucks, trailers and tankers, storage of raw materials in bunkers and stockpiles, transfer of raw materials by front end loaders, conveyors, hoppers and agitators and leakage or spillage of raw materials from silos, inspection covers and duct work.

2.4.2 Characteristic of Dust Particles

The physical characteristics of particulates include their size distribution and mass concentration. As for the size, their diameter can vary from range of nanometers (nm) to ten of micrometers (µm). Size is the single most crucial determining factor of the particles' properties. Size also has effect on the physical and chemical properties, formation, transformation, movement, and removal from the atmosphere. Ambient levels of mass concentration are measured in micrograms per cubic meter whereas size of particulates is commonly measured in aerodynamic diameter. Particulate matter's aerodynamic diameter which exceeds 2.5 microns is called as coarse particles. On the other hand, particles that are smaller than 2.5 microns (PM2.5) are defined as fine particles (World Bank Group, 1998).

Particles of any substances which are less than 10 or 2.5 micrometres diameter consist of a huge fraction of dust that is able to be inhaled deep into the lungs. Particles which are bigger than this size would most likely be trapped in the nose, mouth or throat, unable to travel further. Other properties and amount of dust or suspended particulate matter are directly influenced by existence and activity of sources. Once the dust particles are formed, their size and proportion change by various processes such as evaporation or condensation process, coagulation or by chemical reactions (Afroz et al., 2003).

Jonsson et al. (2004) mentioned in their study that meteorological factors are most crucial in governing the concentration variations of particulate matter. These factors include wind speed and direction, temperature, amount of precipitation, and the height of the atmospheric boundary layer. The highest PM concentrations are often reported during stable meteorological conditions such as inversion with low wind speeds (Pohjola et al. 2004). The physical and chemical processes affecting the particles too are regulated to a great extent by meteorological factors.

The chemical composition of the particulate matter is also important. The chemical composition of PM is highly variable due to pollution sources, chemical reactions in the atmosphere, long-range transport effects and meteorological conditions. Absorption and heterogeneous nucleation of vapour phase pollutants onto existing particles can create toxic particulate matter (US EPA, 2010). The chemical properties vary depending on sources of particles. It is important to note that particulates are not one particular chemical substance but a classification of particles by size rather than chemical properties.

The acid component of particulate matter and most of its mutagenic activity are generally contained in fine particles, although some coarse acid droplets are also present in fog. Particles interact with various substances in the air to form organic or inorganic chemical compounds. The most common combinations of fine particles are those with sulphates (World Bank Group, 1998). The relative abundance of the major chemical components, termed as 'bulk chemical composition and also about trace element and strong acid contents were reviewed in the studies of Harrison and Jones (1995) and Harrison and Yin (2000).

In addition to the bulk composition, Harrison and Yin (2000) also discussed trace element and strong acid contents. In the United States, sulphate ions account for about

40% of fine particulates and may also be present in concentrations exceeding 10 μg/m^3 (US EPA, 2010).

2.4.3 Health and other issues related to dust particles

Dust emitted from cement plants are found to affect respiratory symptoms and enters the airways of lung and cause reduced lung function (Zeleke et al., 2011). Around 2.1 million of premature deaths estimated per year globally in association to inhalation of particulate matter which is highly related with many adverse health effects such as cardiovascular and pulmonary diseases (Fantke et al., 2015). The cement industry has a significant contribution to the environment unevenness, especially in terms of air quality.

Pollutants emitted from cement plants, especially metals, get distributed in soils and may affect vegetation and enter food chain via crops and water. There are chances of human direct exposure to dust generated by emissions from cement plants. Indirectly, human health could be negatively affected through the ingestion of contaminated foodstuffs, drinking water, and through chemical absorption contaminated soils into skin. The risk of being injured or ill depends on duration and level of exposure although each individual's sensitivity also plays an important role. Different cements plant has different ingredients and many of them contain hazardous substances such as chromium, lime, nickel, gypsum, crystalline silica (quartz) and cobalt compounds. Inhalation of chromium compounds found in some cement dusts can potentially cause cancer while inhalation of silica dust can cause silicosis or other potentially fatal lung diseases (Green N8 Residents Group, 2004).

2.4.3.1 Health issue related to cement dust case report (Joshi et al., 2011)

Case study of a 75-year-old woman with a history of cough with expectoration and breathlessness on exertion for 20 years was presented. A diagnosis of chronic obstructive pulmonary disease (COPD) with right heart failure was made. Being a nonsmoker, this woman was a construction laborer involved in mixing concrete and tiling, have had exposure to cement dust for 30 years. She had been using gas stove for cooking for approximately one to two hours daily and there was no history of exposure to passive smoking or biomass fuel.

Based on the interrogation, the woman had been found to be using both white or black cement and masonry sand at her workplace. The case report suggested that the woman suffers from emphysema which was most likely cement exposure-related, since there was no prior exposure to biomass fuel or passive smoking. Increased mortality has been noted from COPD among construction workers exposed to organic dust as compared to unexposed construction workers. However, the case study failed to discover the exact mechanism by which cement dusts affects the lungs. It was yet to be determined whether these effects are directly due to cement dust or mediated by a metabolic product of cement dust.

2.4.4 Environmental issues from Cement Industries

Cement industry is one of the major sources of carbon emissions (CO_2) through the combustion of fuels as well as through calcinations of limestone in the manufacture of clinker, an intermediate product responsible for about 70-80% of total energy consumed in cement production (Worrell et al., 2001). This industry therefore plays a pivotal role when exploring carbon-emission reduction options to deal with the threats posed by global warming and related climate change effects. High concentrations of particles emitted from cement plant may affect the health and property of homeowners living adjacent to the plant.

There are numerous common complaints on cement plant commonly received from residents nearby cement plants. The complaints include specific problems about odours, blasting, noise, respiratory problems and corrosive dust on cars (Abdul Wahab et al., 2006). Meanwhile, significant quantities of various hazardous air pollutants (HAPs) are emitted into the atmosphere, including the conventional air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), and particulate matter (PM), as well as various toxic heavy metals (HMs) like mercury (Hg), cadmium (Cd), chromium (Cr), lead (Pb), zinc (Zn), arsenic (As), nickel (Ni) and copper (Cu), which aggravates local and regional environmental problems as well as contributing to human health damage and climate change. Cement production is claimed to be the largest source of PM emissions, accounting for 20 to 30% of national total emissions and 40% of total industrial emissions in China (CEYRC, 2013).

The atmospheric particles can have as consequence the reduction of biodiversity and the quality of goods and services offered by the ecosystems. The main impacts of the cement activity on the environment are the broadcasts of dusts and gases. These particles or dusts are numerous and varied. The extensive extraction of raw material does not only add various pollutants or contaminants to the environment but also disturb the total ecosystem of the area (Zerrouqi et al., 2007).

2.4.5 Current management strategies and technologies available for dust control in cement industry

Dust emissions can occur in different ways, depending on the surface condition and has the capacity and speed of transportation. Dust emission pathways can be minimized by the various measures. Frequent spraying of water, oil, or other materials on soil stabilization can moist the surface and minimize dust from being spread. Paving the way periodically to remove dust collected from the surface also helps to minimize dust. Reducing road traffic transportation by replacing smaller with larger vehicles reduces the speed of vehicles which reduce fugitive emission of dust (Edalati et al., 2014).

Studies suggested some strategies to control and reduce pollution, such as creating a fully equipped indoor dust filter holder for single packing. Dust filters improve performance, according to the retrieval and reuse of materials (especially waste), shaving mill cement and raw materials, reduce energy consumption, eliminate storage of clinker dust and indirectly reduce energy consumption (Jahromi and Hashemi, 2013).

Reducing the atmospheric emissions is one of the important criteria in order to improve the overall efficiency of cement plant operations. For collection and recycling of dust, units that are well designed and well maintained can usually achieve generation of less than 0.2 kilograms of dust per metric ton (kg/t) of clinker, using dust recovery systems. Five main dust emission control techniques that are commonly available are gravity settling chamber, mechanical collectors, particulate wet scrubbers, electrostatic precipitators and fabric filters.

Gravity settling chamber depend on gravity settling to eliminate particles from the gas stream and are used only for very large particles in the upper end of the super coarse size range (approximately 75 micrometre and larger). Mechanical collectors utilize the inertia of the particles for collection whereby the particulate-laden gas stream is forced to spin in a cyclonic manner. As the mass of the particles causes them to move toward the outside of the vortex, the larger-diameter particles enter a hopper below the cyclonic tubes while the gas stream turns and exits the tube (Khattak et al, 2013).

In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants. Wet scrubbers remove dust particles by capturing them in liquid droplets. It can remove pollutant gases by dissolving or absorbing them into the liquid droplets.

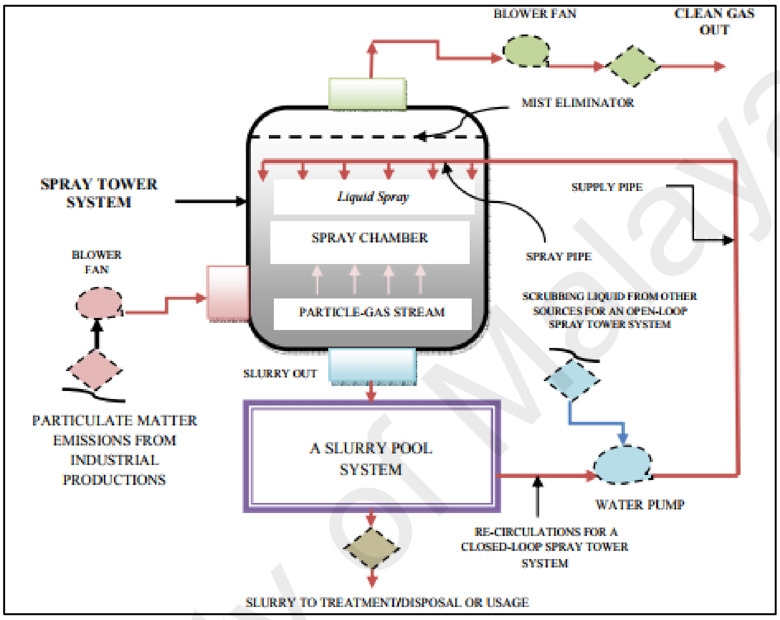

Figure 2.3: Typical wet scrubber process (Bashir and Momoh, 2012)

An electrostatic precipitator, (ESP) is a dust control device that removes particles from a flowing gas (such as air) by using the force of an induced electrostatic charge (Zimwara et al., 2012). Fabric filtration dust control technology uses a number of filter bags hung in parallel in which gas stream containing dust is passed through. Cleaning dislodges the dust that has accumulated on the filter bags and the frequency of cleaning is controlled either on the time basis or pressure drop level.

A positive pressure baghouse could be open to the atmosphere or closed whereas the negative pressure baghouse is of a closed type. In the case where the gas stream contains hazardous air pollutants to be cleaned, closed design is selected to prevent release of captured pollutants (DOE, Malaysia).

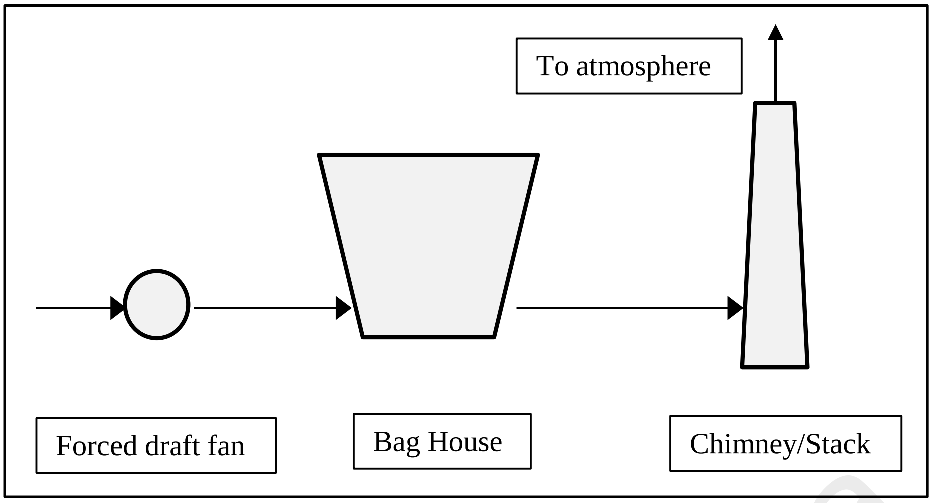

Figure 2.4: Positive–Pressure Bag House

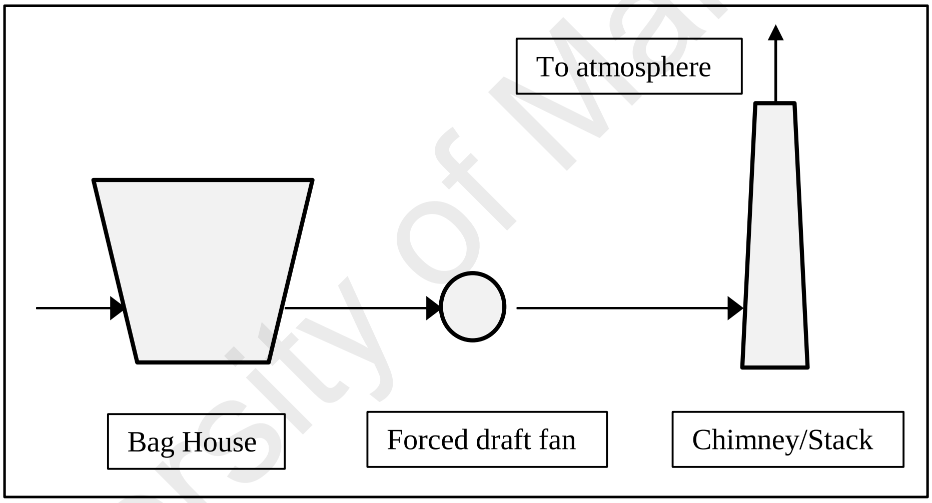

Figure 2.5: Negative–Pressure Bag House

In negative-pressure bag house, the fan is downstream or after the filter where air or gas is pulled through the filter. The bag house requires more structural reinforcement due to suction on baghouse shell.

2.5 Hierarchical management strategies

Waste management hierarchy indicates an order of preference for action to reduce and manage waste, and is usually presented diagrammatically in the form of a pyramid. The hierarchy captures the progression of a material or product through successive stages of waste management, and represents the latter part of the life-cycle for each product. The aim of a waste hierarchy is to extract the maximum practical benefits from products and generate the minimum amount of waste. Proper application of the waste hierarchy can provide several benefits. It can help prevent emissions of greenhouse gases, reduces pollutants, save energy, conserves resources, create jobs and stimulate the development of green technologies.

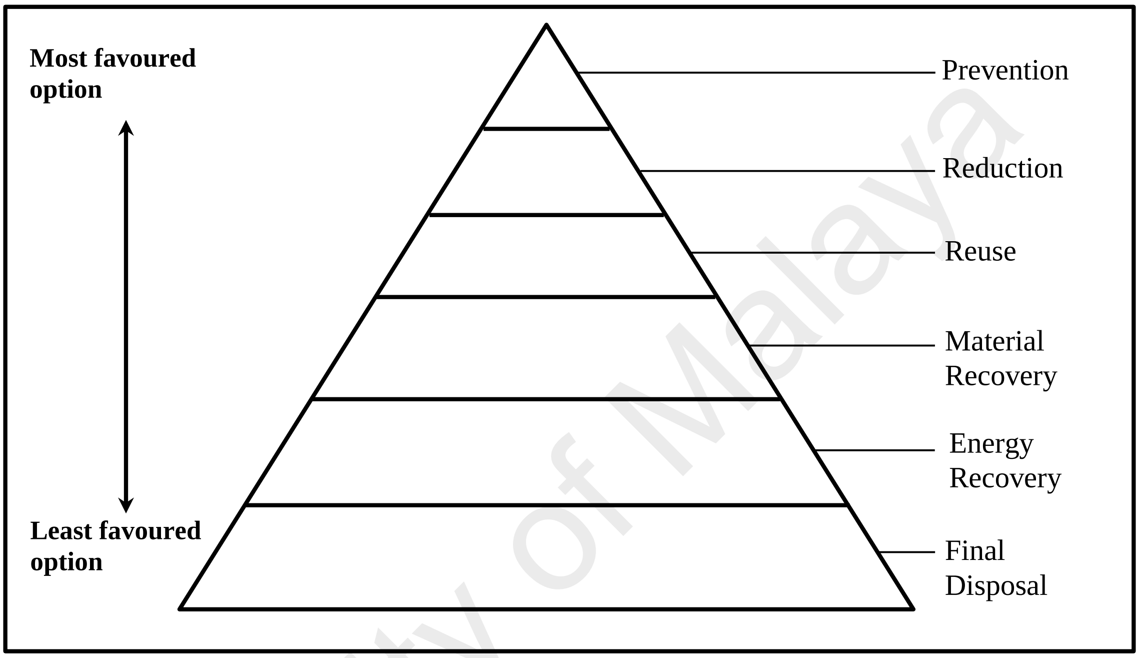

Figure 2.6: Waste management hierarchy

The prevention of waste is the paramount point in the waste hierarchy. Prevention or reduction minimizes the generation of waste products in the first place. Prevention usually results in the least environmental and economic life cycle costs because it requires no collecting or processing of materials. It also typically produces significant benefits in terms of production efficiencies and use of resources. The reuse of waste is the next most desirable option. Reuse is the using again of a material without any structural changes made to it. Reusing waste often requires collection but relatively little or no processing is required.

The recovery of waste is further separated into two categories: recovery of materials and recovery of energy. The choice of recovery is usually based on higher benefits to the environment and human health although the recovery of materials is the most often the more preferred option. Recovery of materials includes activities such as recycling and composting. These activities generally require a collection system, as well as a method of material processing or conversion into a new product.

Recovery of energy, such as incineration, is usually the less preferred option. Final disposal is always a last resort, only considered once all other possibilities have been explored. Before final disposal, a considerable amount of pre-treatment is necessary. Pre-treatment includes physical, thermal, chemical, or biological processes which change the characteristics of the waste in order to reduce the quantity and/or harmfulness of the waste. Landfilling is final disposal.

2.6 Summary of literature review

The following are the summary of literature review research that has been conducted:

1) The preparation of cement involves various processes such as mining; crushing, and grinding of raw materials; calcining the materials in a rotary kiln; cooling the resulting clinker; mixing the clinker with gypsum; and milling, storing, and bagging the finished cement.
2) The dust generated in the cement plant is a loss of natural resources and creates issues to surrounding, environment and health of workers and nearby community.
3) The current control system in the industry is not fully sufficient and sustainable.
4) Hence, hierarchical dust management system is required. A waste hierarchy is aimed to extract the maximum practical benefits from products and generate the minimum amount of waste.

CHAPTER 3: METHODOLOGY

In this chapter the research methodology employed in the study was documented. The chapter highlights the premise selection, data collection and analysis method to be used in this study.

3.1 Overall Methodology Flow Chart

Figure 3.1 below shows the flow chart for overall process involved in the study.

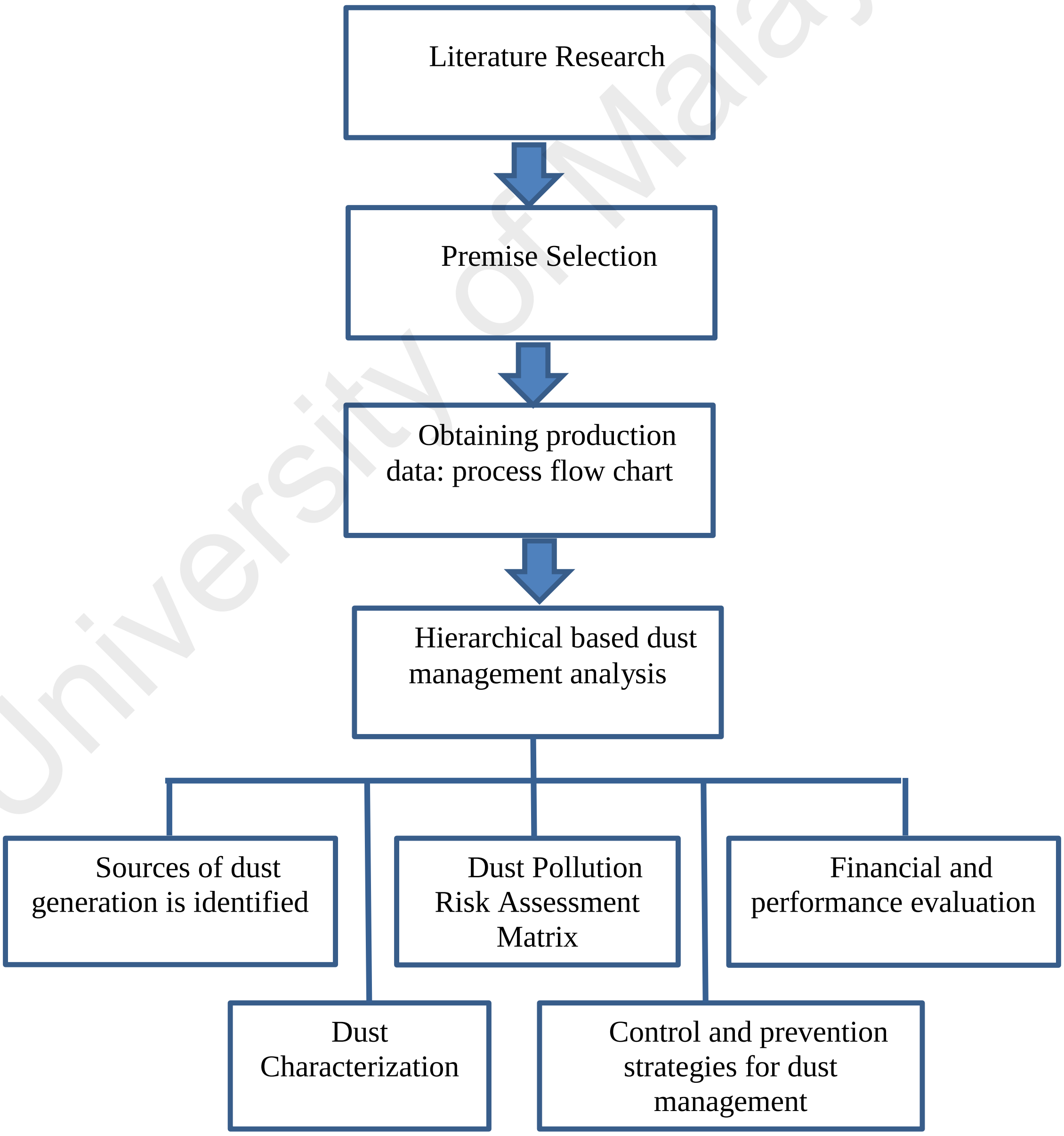

Figure 3.1: Methodology flow chart

3.2 Premise Selection

Cement manufacturing industry in Malaysia is mostly scattered around the East Coast which can be further divided into Northern Region, Central Region and Southern Region. High accessibility in the East Coast of Malaysia is an advantage to select any premise that falls under this region. A letter of permission was sent to the plant management in order to enter the plant and obtain the necessary data. In further stage, a non-disclosure agreement (NDA) was achieved with the plant to protect the plant confidentiality. Basic information of the company was retrieved from the plant is presented in table below.

Table 3.1: Selected Premise Information

No.	Item	Description
1.	Company Name	ABCD Sdn. Bhd.
2.	Built up area	1162.25 acres
3.	Production Capacity	2.35 million tonnes of cement per annum
4.	Product Range	Ordinary Portland Cement, Portland Composite Cement, Masonry Cement, Portland Pulverised-Fly Ash Cement and Portland Limestone Cement
5.	No. of Employees	200-250 employees
6.	Working Hours	Operators: Shift 1 (7am-3pm), Shift 2 (3pm -11pm) Shift 3 (1pm -7am) Office : 8am -5pm
7.	Head Office	Kuala Lumpur
8.	Plant Location	Central Region

3.3 Obtaining process flow of the plant

Process flow in every cement manufacturing plant is different due to the plant capacity and usage of wide range of raw material, additives, equipment and technology. The process flow chart obtained from the plant was first used to study the process. The equipment and technology being used in each process line can be seen from the process flow obtained. The process flow obtained from ABCD Sdn. Bhd. is simplified and further explanation on the processes is shown chapter 4. This is due to the plant confidentiality agreement since the process flow has information on the ingredients.

3.4 Data Collection

In any cement manufacturing plant, dust is found to be the primary emission. In ABCD Sdn. Bhd., the plant has employed mechanical collectors, from cyclone collectors to a much smaller size like gravity settling chambers, fabric type dust collectors, gravel bed filters and finally electrostatic precipitators to control dust pollution. The plant has always strived to meet the emission standards. Hence, they utilized combinations of various dust collectors, depending on the intensity and temperature of the effluents. Each dust collector was evaluated by its efficiency, where the ratio of the amount of dust precipitated to the total quantity of dust introduced into the collection device was calculated and shown in percentage.

Process flow chart was only helpful to give an overview of the overall process to produce the end product. The data collection was required in this methodology to further understand the dust generation in each process including the material transfer and shipping. Once the flow chart was obtained, the mechanism of dust generation was further elaborated.

3.5 Dust characterization methods

Dust generation point to be identified in alphabetical order. The type of dust generated was classified into fugitive source and point source. For each dust generation point defined in the process flow, the mechanism of the dust generation was determined. These source types were further classified as following:

a. Raw Meal Dust

b. Feed Material dust

c. Kiln Dust

d. Clinker dust

e. Cement Dust

3.6 Calculating total dust emission per annum in production line

Based on the process flow chart with additional data obtained from plant, the amount of material in and out of each major process line was identified. The loss of material occurred in each process equipment was calculated. A mass balance was generated from the information obtained. Since the main focus of the study was on dust emission, the plant had agreed to provide the emission factor of dust being generated for every tonne of cement produced.

Based on the total production of cement per annum, total production per day was determined using below equation:

$$\textit{Per day production capacity} = \frac{Plant\ cement\ production\ per\ year}{Number\ of\ working\ days}$$

= Tonnes of cement produced per day (TPD) .... (Equation 3.1)

Using the emission factor obtained from the plant, the dust generated in each point without installation of air pollution control device (APCD) was calculated using below equation:

$$\begin{array}{l} \textit{Emission without APCD for} \\ \textit{6900 TPD cement production (kg)} \end{array} = \begin{array}{c} \textit{Emission Factor} \\ \textit{(in kg/tonne)} \end{array} \times \begin{array}{c} \textit{Tonnes per day (TPD)} \\ \textit{of cement produced} \end{array}$$

Equation 3.2

From the figures obtained, dust generated annually from each point was also calculated and tabulated. Later, the dust control devices used in each dust generation point were identified and the efficiency of these equipment were obtained from the process department. Dust emission after the installation of APCD was calculated using below equation:

Emission with APCD for
6900 TPD cement production (kg) = Emission per 6900 TPD (kg) x (1 – Efficiency)

Equation 3.3

Dust emissions per annum for both with and without installation of APCD in ABCD Sdn. Bhd. were then tabulated, clearly stating the efficiency of each device used in every process.

3.7 Dust pollution risk assessment matrix

Table 3.2: Risk rating guidance

		Possible Consequence		
		1	2	3
Probability	1	1	2	3
	2	2	4	6
	3	3	6	9

Low Impact
Medium Impact
High Impact

Based on the amount of dust emission obtained, assessment of possible risk of dust and probability of occurrence were done. The risk assessment was done using Table 3.2 as guidance. The impacts of this dust generation were classified in this section as high, medium and low. Once the risk assessment was done, pollution control and prevention strategies based on waste management hierarchy were proposed. The waste management hierarchy was listed in order as below.

1) Prevention of dust generation
2) Reduction on the dust generated
3) Reusing the dust generated
4) Recover material from dust generated to be used in different process
5) Best disposal of dust generated with less impact to surrounding and environment.

3.8 Performance & financial evaluation method

Once hierarchical based integrated dust management system (HBIDMS) were established in this study, estimation of reduction factor was obtained from the plant, based on data before and after the implementation of the strategies. Emission per annum before and after implementation of HBDIMS was shown and the cost for each was calculated. Market price of cement was obtained to calculate cost of reduction in dust emission. Annual savings after implementation of the HBDIMS is calculated based on the emission per annum and the price of the cement. The cost of proposed strategies is estimated based on previous project done in plants own by ABCD Sdn Bhd. Payback period is calculated using below equations.

$$\text{Payback Period} = \frac{\text{Cost of implementations of HBIDMS}}{\text{Annual Savings}} \quad \text{.......... (Equation 3.4)}$$

Performance evaluation is done by visual inspection on the plant surrounding and the equipment. Next the emissions data for point sources dust is to be obtained from plant and the ambient air quality check to be carried out for the fugitive source dust.

3.9 Safety precaution

Cement industries are considered as heavy industries as it involves megastructures, high fuel consumptions, high voltage electric equipment, very high temperatures and pressurized equipment. Working at height, confined space and hot working environment is common in a typical cement manufacturing plant. ABCD Sdn. Bhd. highly concern on the safety of the workers due to the high potential of hazard and risk at the plant.

A safety briefing done by the safety department from the plant is compulsory in order to access the plant area, which includes safety precautions to be taken and safety measures that need to be followed. A safety pass is given once the safety briefing is complete which can be used to enter the plant. There are three type of pass given by this plant

a. Visitor pass: only allow access to office area.
b. Red Pass: one can visit plant accompany by plant personnel
c. Safety Pass: Issue by plant after safety induction and allow access to plant area

The personal protective equipment (PPE) needs to strictly adhere to the plant guidelines and any deviations is not compromised by the plant. The preparation of PPE included safety shoes, long sleeve safety jacket with luminescence reflector, safety helmet with luminescence stripes and safety goggle

CHAPTER 4: RESULT AND DISCUSSION

4.1 Process Flow

The lime stones received from the quarry were crushed in single stage or double stage high speed impactor. This process includes primary and secondary crushing of raw materials. Raw material such as limestone was ground into powder and proportioning of each raw material was done. In dry mixing and blending process, the materials were blended. Then, raw meal was fed to the top of a series of cyclones passing down in stepwise counter-current flow. The raw material was subjected to high heat of hot exhaust gases in preheat process.

The exhaust gases left the preheater at a temperature of 300-360° C. From the preheater, materials entered the kiln, where it rotates and with this rotation, the ground raw material moved closer to the flame. The temperature increased in kiln, as sequence of physical and chemical changes began to occur. At about 1500◦ C, calcium silicates and aluminates were produced. The hot temperature was cooled down in clinker cooler. There were two types of clinker coolers in ABCD Sdn. Bhd., namely Planetary Cooler and Grate cooler.

Since the planetary cooler was at the end of the outlet of the kiln, the air blown out was utilized for secondary combustion in the kiln. Hence, there is no particulate emission. But as for grate cooler, only a part of the air blown out was used for combustion in the kiln and the rest was omitted. The clinkers were stored after the cooling process. In cement grinding step, accurate proportioning of all components was ensured and the clinkers and gypsum were ground to be fine cement. The process flow and dust generation points in the processes are shown in Figure 4.1.

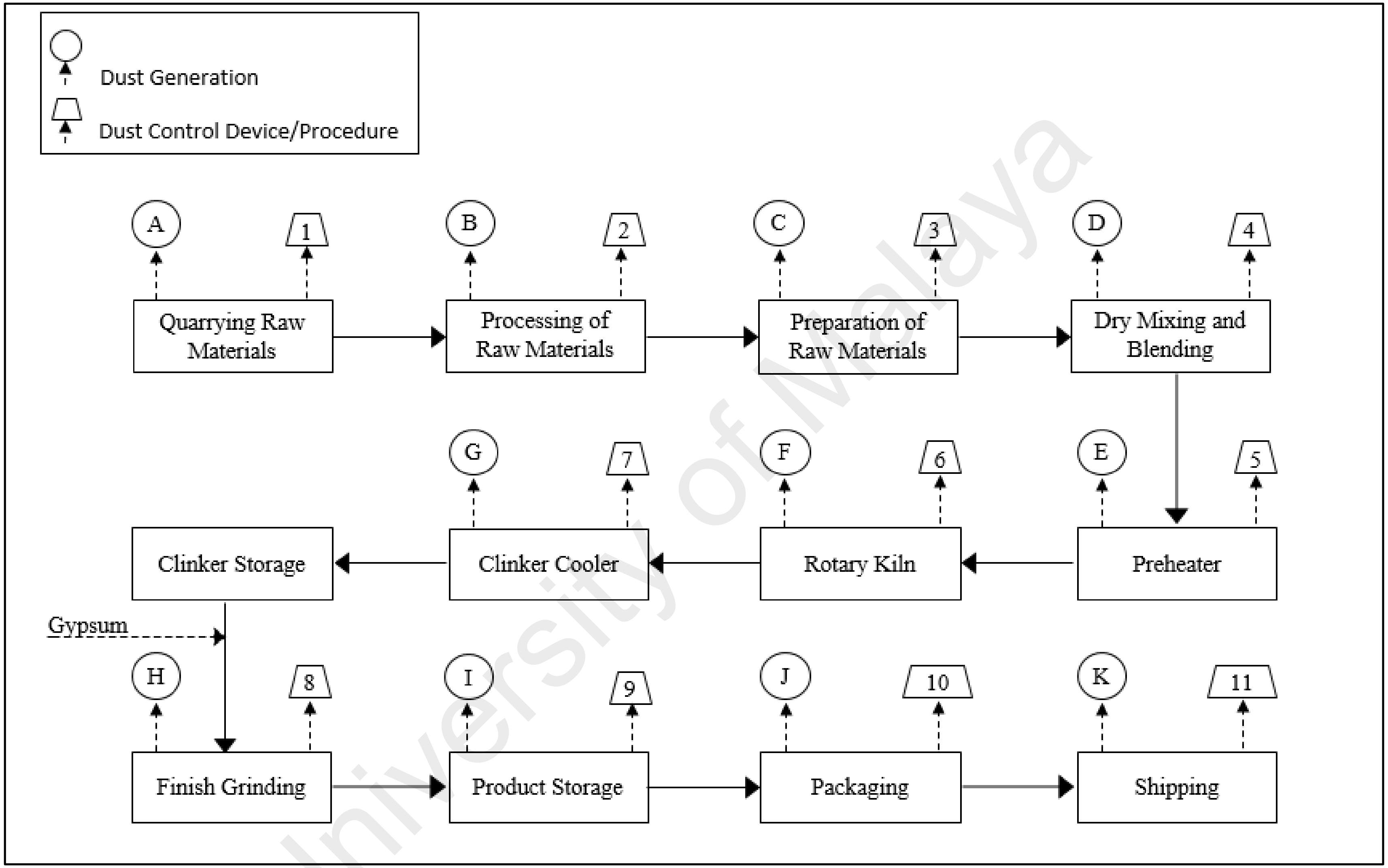

Figure 4.1: Process Flow Chart in ABCD Sdn. Bhd.

4.2 Mechanism of dust generation

Table 4.1: Mechanism of dust generation

Dust Generation Point	Process Description	Source of Dust	Type of Dust Generated	Mechanism of dust generated
A	Quarry	Fugitive	Raw Material Dust	Blasting, stockpile, drilling, transfer point and conveying
B	Raw Material Processing	Fugitive	Raw Material Dust	Unloading raw material, crushing, screening, raw material transfer
C	Raw Material Preparation	Point	Raw Material Dust	Raw material grinding
D	Mixing and Blending	Point	Feed Material	Raw material mixing
E	Pre Heater	Point	Feed material	Air flow turbulence
F	Kiln Emission	Point	Cement kiln dust	High temperature and rotation of kiln
G	Clinker Cooler	Point	Clinker dust	Air flow turbulence at clinker cooler
H	Cement Mill Grinding	Point	Cement dust	Grinding
I	Cement Storage	Point	Cement dust	Air entrainment
J	Packaging	Fugitive	Cement dust	Material transfer, handling
K	Shipping	Fugitive	Cement dust	Unloading

Based on the process flow chart and the nature of the process the dust generation point has been classified into fugitive and point source. The dust generated can be classified further into raw material dust (generated at initial process of raw material processing and preparation), feed material (dust from the feed of material to the kiln), cement kiln dust (dust generated from the kiln), clinker dust (dust generated from products of kiln, clinkers) and finally cement dust (where further grinding to extra fine particles together with gypsum to produce the end product).

Fugitive dust generation occurs in the beginning (quarry and raw material processing) and at the end (packaging and shipping). The mechanism of creation of this fugitive dust includes crushing, screening, blasting, drilling, conveying, material transfer, unloading and handling. This shows the fugitive dust occurs at process other than enclosed air stream. Figure 4.2 shows the fugitive dust generation due to stockpile and material transfer in limestone quarry.

Figure 4.2: Dust Generation Point A (Quarry – stockpile & material transfer, fugitive dust)

Point source dust generation occurs throughout the process where air or gas flow in the system in a confined flow stream. This includes major processes such as kiln, preheater, clinker cooler and cements mill grinding. Figure 4.3 shows the emission from point source dust generated in kiln and preheater even after use of air pollution control device, electrostatic precipitator (ESP).

Figure 4.3: Emission from dust generation point E (Pre-heater) & F (Kiln) – point source dust

4.3 Total dust emission per annum

The plant production per year is 2.35 million tonnes of cement. Taking into annual shut down period which is around 20 days the production capacity of the plant is 6900 tonnes per day (TPD).

Table 4.2: Emission factor and dust emission per annum without Air Pollution Control Device (APCD) in ABCD Sdn. Bhd.

Dust Generation	Without APCD		
	Emission Factor* in kg/tonne of cement produced	Emission for 6900 TPD cement (tonne)	Emission per annum (tonne)
Quarry	6.00	41.40	14,076.00
Raw Material Processing	8.00	55.20	18,768.00
Raw Material Preparation	17.00	117.30	39,882.00
Mixing and Blending	14.00	96.60	32,844.00
Pre Heater	21.00	144.90	49,266.00
Kiln Emission	23.00	158.70	53,958.00
Clinker Cooler	18.00	124.20	42,228.00
Cement Mill Grinding	221.00	1,524.90	518,466.00
Cement Storage	3.00	20.70	7,038.00
Packaging	2.00	13.80	4,692.00
Shipping	1.00	6.90	2,346.00
	Total	2,304.60	783,564.00

* Emission factors were obtained from plant process department

The emission factor obtained from the plant showed the highest at cement mill grinding. This is because at this process stage, the cement particle size is very small and the process involves mechanical grinding where dust is easily generated. The gypsum addition to the process is also another cause for high dust generation due to free fall of gypsum at the feed which can cause air entrainment and the dust particle can move freely from the falling stream.

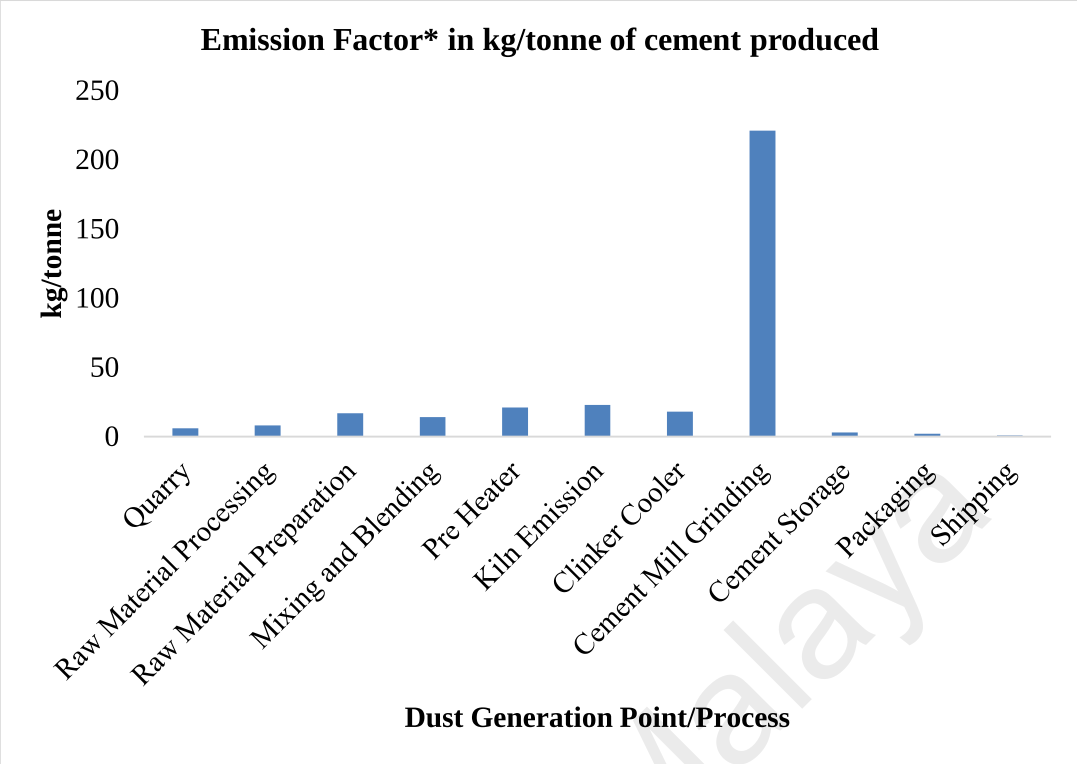

Figure 4.4: Emission Factor vs Dust Generation Points

Cement storage, packaging and shipping have the lowest emission due to the process parameters which are at ambient temperature and pressure compared to other processes. The emission factor for dust generation at quarry and raw material processing are low because it involves only fugitive source where the process takes place in wide open area. Kiln, pre-heater, clinker cooler, raw material preparation, mixing and blending have high emission factor because these processes involve air flow in a confined space which produces significant amount of point source dust.

4.3.1 Dust control devices used in the company.

The plant employed mechanical collectors, from cyclone collectors to much smaller size like gravity settling chambers, fabric type dust collectors, gravel bed filters and finally electrostatic precipitators to control the dust emission throughout the manufacturing process. In order to meet the emission standards, combinations of various collectors were employed, depending on the intensity and temperature of the effluents. Dust collectors were evaluated by their efficiencies. The efficiency of dust collector equipment was the ratio of the quantity of precipitated dust to the total quantity of dust introduced into the collection device expressed in percentage.

4.3.1.1 Gravity settling chamber

Gravity settling chamber (GSC) was used for pre-cleaning of high dust laden gases. The chamber works on the principle of removing the dust by reducing the velocity of the gas or air stream. For removing of fine dust particles, for instance in the range of 20 microns, large settling chambers are required. The efficiency of the GSC falls in a range of 70% to 90% depending on the size of the particles which normally range 10µm - 50µm.

4.3.1.2 Cyclone

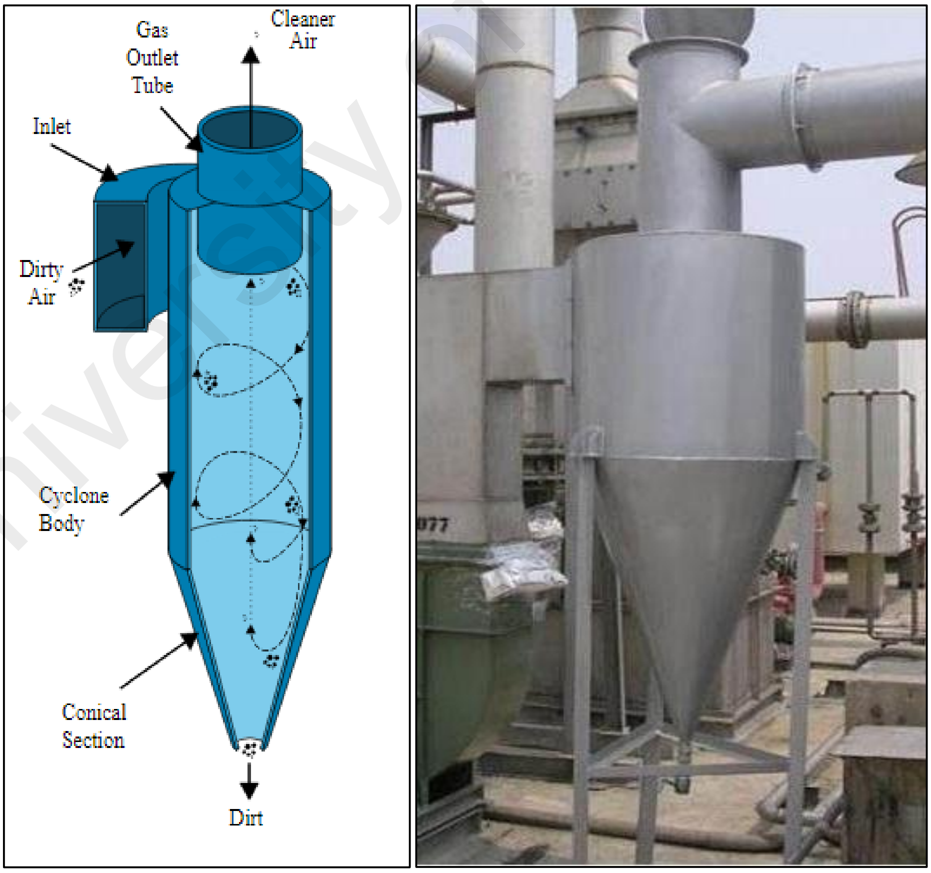

Figure 4.5: Cyclone in raw material processing (crushing of limestone)

Cyclone consists essentially of two sections which are a cylindrical and a conical one. At the top of the cylindrical section the gas enters tangentially and spirals along the walls downward into the conical section. Then, it starts to occupy the center space of the cyclone and spirals upward to the outlet thimble. Centrifugal forces push the dust particles towards the wall where they accumulate and descend down by gravity. Most of the particles fall down to the bottom into a hopper where the particles are removed by rotary valves or screw conveyors. In this plant, cyclones are used for application with rotary kiln, clinker coolers, crushers, dryers, grinding mills, conveyor and others. Efficiency of cyclone ranged from 75% to 85% (10µm-30µm).

4.3.1.3 Multiple cyclones

Multi-cyclones are enclosed units and arranged in banks for parallel flow with feed gas from a plenum chamber and with a common dust discharge hopper. In ABCD Sdn. Bhd., multi-cyclones act as major component in collection of dust from kiln gases, grate clinker coolers, dryers and grinding mills. Efficiency of these multi-cyclones ranged between 85 % – 94 %.

Figure 4.6: Multi-cyclone in clinker cooler

4.3.1.4 Fabric filters

Fabric filters were used in various processes in the plant, including cement mill grinding, cement storage and packaging. Operating principle of a fabric filter is shown in Figure 4.7.

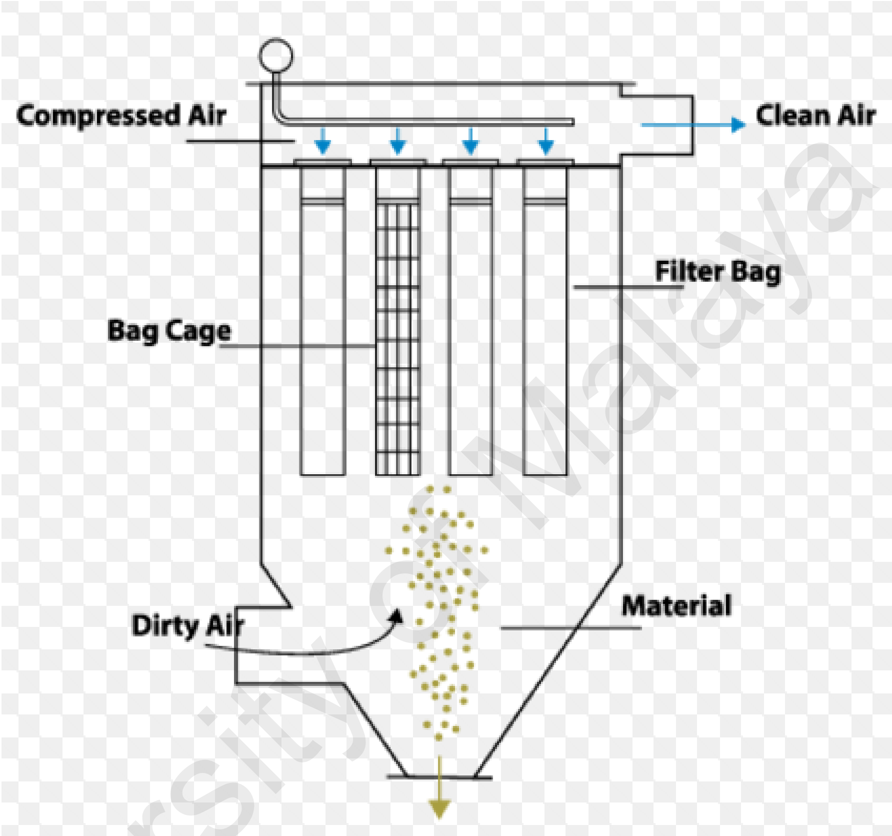

Figure 4.7: Operating principle of fabric filter

The dust laden gases flow through a porous medium of the filter fabrics and deposits particles in the voids. After filling the voids, a cake starts to build up on the fabric's surface which does most of the filtering. During the pre-coating period which lasted only moments, the efficiency may drop. When the dust layer on the fabric becomes too thick, an increase in pressure drop results thus requires cleaning of the fabric. Cleaning is accomplished periodically mostly response to a timer. Efficiency of fabric filters used in this plant was high, about 99.5 % for particles size less than 10μm.

Figure 4.8: Fabric filter baghouse installed in packaging process

4.3.1.5 Electrostatic precipitators

The principle of this type of dust collection is based on the utilization of the effect of gas ionization in a strong electric field which is formed by discharge electrodes and collecting electrodes. The ionized particles, due to the electrostatic force, are diverted towards the grounded plates. Particles build up on the collection plates and are removed from the air stream. Efficiency of electrostatic precipitators used in ABCD Sdn. Bhd. ranged from 95 % to 99 % for particles size less than 10µm.

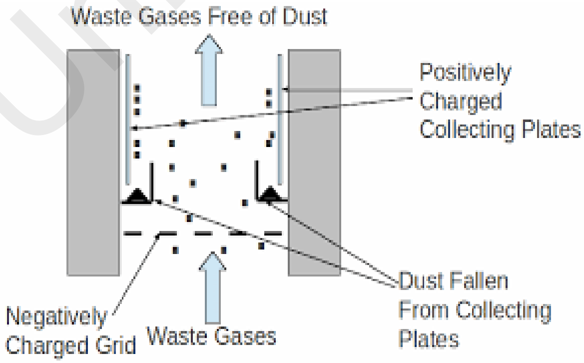

Figure 4.9: ESP installed for preheater and kiln dust control.

Table 4.3: Yearly possible scenario of dust emission

Dust Generation	Without Control Device		With Control Device			
	Emission for 6900 TPD cement (tonne)	Emission per annum (tonne)	Dust Control Device	Efficiency	Emission for 6900 TPD cement (tonne)	Emission per annum (tonne)
Quarry	41.40	14,076.00	• Multi – Cyclone • Fabric filter	95.00%	2.07	703.80
Raw Material Processing	55.20	18,768.00	• Gravity Settling Chamber Cyclone	97.50%	1.38	469.20
Raw Material Preparation	117.30	39,882.00	• Cyclone Fabric Filter	99.50%	0.59	199.41
Mixing and Blending	96.60	32,844.00	• Cyclone Fabric Filter	99.50%	0.48	164.22
Pre Heater	144.90	49,266.00	• Multi-cyclone ESP	99.50%	0.72	246.33
Kiln Emission	158.70	53,958.00	• ESP	99.00%	1.59	539.58
Clinker Cooler	124.20	42,228.00	• Multi-cyclone ESP	99.50%	0.62	211.14
Cement Mill Grinding	1,524.90	518,466.00	• Cyclones Fabric Filter	99.95%	0.76	259.23
Cement Storage	20.70	7,038.00	• Fabric Filter	99.90%	0.02	7.04
Packaging	13.80	4,692.00	• Fabric Filter	99.90%	0.01	4.69
Shipping	6.90	2,346.00	• Fabric Filter	99.90%	0.01	2.35
	2,304.60	783,564.00			8.26	2,807.00

*Efficiency of the dust control device is obtained from plant process department

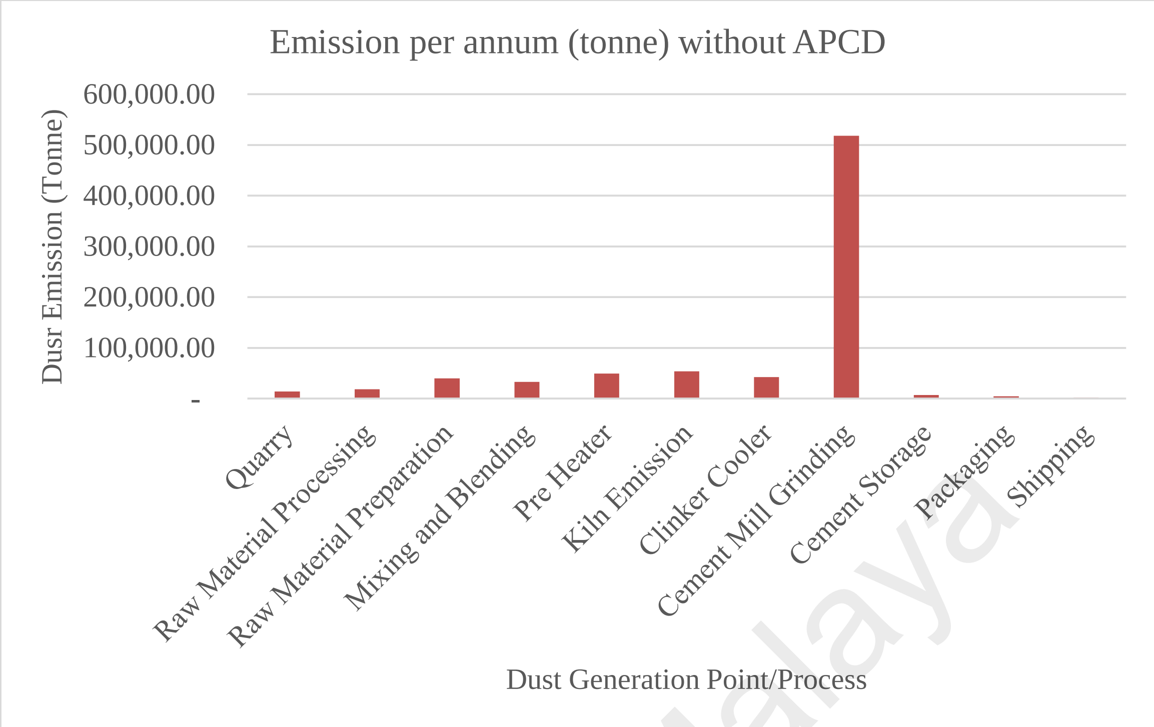

Figure 4.10: Emission per annum (tonnes) vs dust generation points without controls

The total emission of dust without control device is around 800,000 tonnes per annum, which is around one third of the total production capacity of 2.35 million tonnes per annum. Based on Figure 4.10, the highest emission was at the cement mill grinding, as the material size is the smallest in this process and hence it was prone to dust generations. The dust generated in cement plant was not wasted, instead mostly were products that need to recaptured and recycled throughout the process.

Other processes such as kiln, raw material preparation, mixing, blending and pre-heater produces significant amount of emission per annum as well. Low emission was detected in cement storage, packaging and shipping due to the nature of the process which operated mostly in ambient temperature and pressure. Air pollution control devices were used to control this emission; consequently, most of the dust generated was collected in this device and discharged back to the process line.

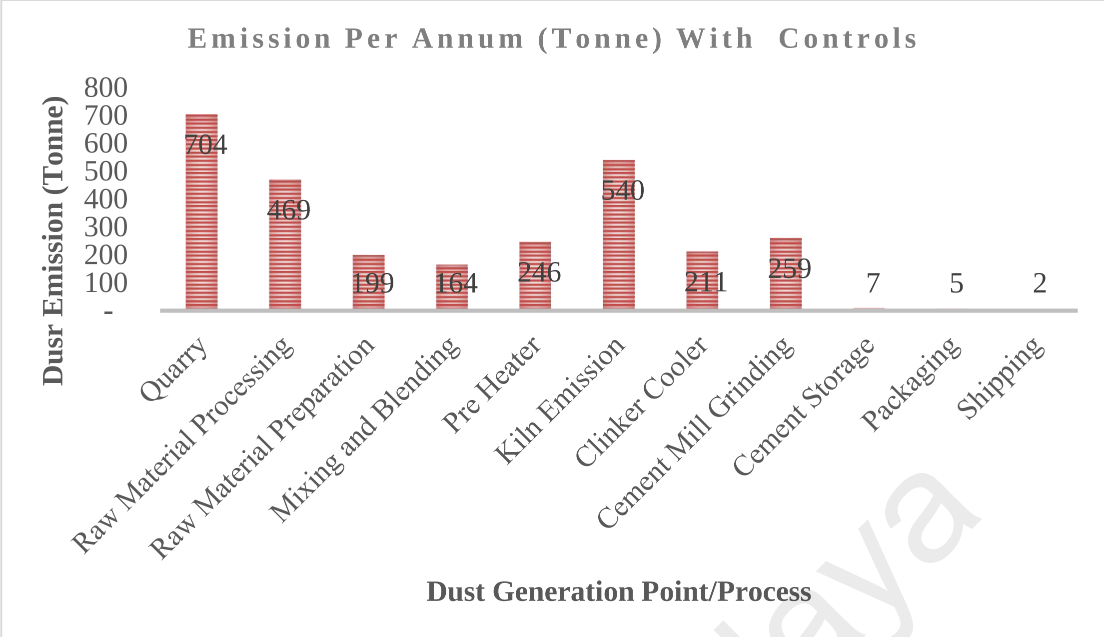

Figure 4.11: Emission per annum vs dust generation points with controls

The total emission after with dust control device is significantly reduce to only 2807 tonne per annum. The reduction is around 99.65% from initial value without any dust control device, 783,654 tonne per annum. Point source dust has been reduced significantly such as cement mill emission is only around 260 tonne per annum from intial value of 520,000 tonne. Point sources dust can be easily reduce using the right dust control device such as cyclone, fabric filters and ESP.

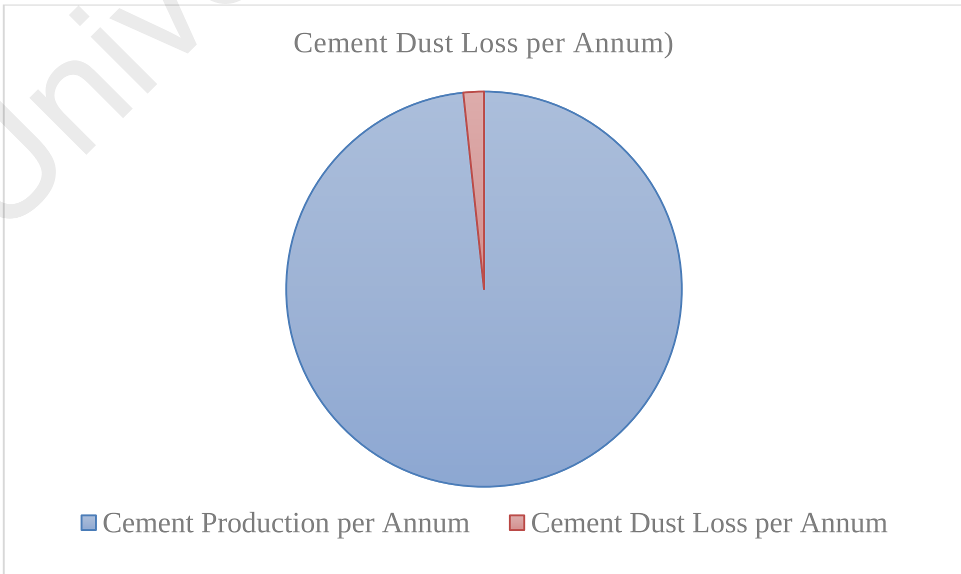

Figure 4.12: Possible Yearly Scenario (Dust Loss)

Fugitive sources dust such as quarry and raw material processing involve more prevention and control technologies since these dust cannot be easily directed to a control device as its not in an airflow stream like point sources dust Figure 4.12 shows total loss of per year (2807 tonne) of dust compared to the total production of cement of the plant (2.35 million tonne).

4.4 Possible risk of the dust

Table 4.4 shows the dust generation points and the risk rating that was associated with the points accordingly. The dust generation points were arranged from highest emission of dust to the lowest range.

Table 4.4: Dust generation points and risk

Dust Generation	Emission for 6900 TPD (kg) with control device	Probability	Possible Consequence	Risk	Impact
Quarry	2070.00	3	3	9	High
Kiln Emission	1587.00	3	3	9	High
Raw Material Processing	1380.00	3	2	6	High
Cement Mill Grinding	762.45	2	2	4	Medium
Pre Heater	724.50	2	2	4	Medium
Clinker Cooler	621.00	3	1	3	Medium
Raw Material Preparation	586.50	3	1	3	Medium
Mixing and Blending	483.00	2	1	2	Low
Cement Storage	20.70	1	1	1	Low
Packaging	13.80	1	1	1	Low
Shipping	6.90	1	1	1	Low

The risk assessment done on the dust generation sources revealed that the highest priority of dust management required in quarry, kiln and raw material processing which has high impact rating. At quarrying and raw material processing, the dust generated were high likely to occur in high volume due to the blasting, crushing, unloading, movement of soil, stone and other materials. This was combined with dusts generated through transportation of raw materials on haul roads. The control device operated at this point had limitation since the dust was fugitive and covered a huge area. Although kiln is more prone to point source dust since the efficiency of ESP was lower than fabric filter, the dust emission at this point was still high.

In preheater kilns, raw materials were subjected to high temperature intimate contact and efficient heat exchange between solid particles and hot gas. This process and in finish grinding of cement, particulate matters or dust generation were highly probable. However, the consequences of the dust generation in these steps were lower than the activities discussed earlier. Hence, the risk impact was deduced to be in medium range. The probability of dust generation was low for other processes involved in the cement manufacturing process. In addition, the probable consequences in case of occurrence were also low, which reduced the impact.

4.5 Control and prevention strategies for dust reduction

ABCD Sdn. Bhd. had taken various steps in controlling dust emission such as installing fabric filters and gravity settling chambers. Based on the risk assessment which included the existing control device, the dust generation points/processes with high and medium impact were chosen for the hierarchical management. High impact of the dust generation are at quarry, kiln emission and raw material processing while medium impact are at cement mill grinding, pre-heater, clinker cooler and raw material preparation. Table 4.5 shows proposal on control and prevention strategies emphasizing the hierarchical management method.

a. Prevention
b. Reduction
c. Reuse
d. Recovery
e. Disposal

Table 4.5: Hierarchy of Dust Management Strategies

Dust Generation Point	Hierarchy Dust Management Strategies				
	Prevention	Reduction	Reuse	Recovery	Disposal
Quarry	• Alternative for blasting, use expansive cement method • Increase number of water spraying system	• Fully enclosed conveying system • Loading/Unloading to be done in enclosed area with APCD	N/A*	N/A	N/A
Kiln Emission	N/A	• To replace electrostatic precipitator to fabric filter	• Stabilization of sludge, wastes, and contaminated soils • Land reclamation	N/A	• Landfilling
Raw Material Processing	• Increase number of water spraying system	• Fully enclosed conveying system	N/A	• Secondary containment act as collection of rocks/dust to be reuse	N/A
Cement Mill Grinding	N/A	• Fully enclosed conveying system	N/A	• Secondary containment act as collection of rocks/dust to be reuse	N/A
Pre Heater	N/A	• To replace electrostatic precipitator to fabric filter	N/A	N/A	N/A
Clinker Cooler	N/A	• To replace electrostatic precipitator to fabric filter	N/A	N/A	N/A
Raw Material Preparation	N/A	• Fully enclosed conveying system	N/A	• Secondary containment act as collection of rocks/dust to be reuse	N/A

*N/A: Not available

The dust generation in quarry can be prevented if an alternative of blasting process was used, which is currently still under research and development worldwide. Water spraying dust suppression system need to be redesigned or added in quantity to cover larger area.

Figure 4.13: Water Spraying System

Process which involves point sources where the dust generation was unavoidable, more management strategies such as to reduce or reuse the dust can be implemented. These strategies are seen as more feasible in such conditions. Fabric filters has better efficiency in dust collection compared to electrostatic precipitator. Thus the existing ESP in kiln, preheater and clinker cooler can be replaced with fabric filter which can reduce the dust emission. Fully enclosed conveying system is capable to reduce the dust generation in quarry, raw material processing and cement mill grinding where the area of this process are far apart. Designated area for loading and unloading with good air pollution control device such as fabric filter can reduce the dust generation cause by this activity.

Cement plant kiln dust is the fine-grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices. Most of the kiln dust are unreacted raw material and are recycled back into the production process. Some kiln dust is reused directly, while some requires treatment prior to reuse and some kiln dust that are not returned to the production process. This unreturned kiln dust to the production process is known for many beneficial use. The kiln dust can be reuse in stabilization of sludge, wastes, and contaminated soils and also in land reclamation. The kiln dust emission might not able to be prevented, instead reduction, reuse and disposal(landfilling) is possible.

4.6 Financial and performance evaluation

Table 4.6: Estimated cost of proposed strategies

Dust Generation Point	Proposed Strategies	Cost Estimated (RM)
Quarry	• Alternative for blasting, use expansive cement method • Increase water number spraying system • Fully enclosed conveying system • Loading/Unloading to be done in enclosed area with APCD	350,000.00
Kiln Emission	• To replace electrostatic precipitator to fabric filter • Stabilization of sludge, wastes, and contaminated soils • Land reclamation • Land Filling	1,200,000.00
Raw Material Processing	• Increase water number spraying system • Fully enclosed conveying system • Secondary containment for crusher act as collection of rocks/dust to be reuse	750,000.00
Cement Mill Grinding	• Fully enclosed conveying system • Secondary containment for crusher act as collection of rocks/dust to be reuse	650,000.00
Pre Heater	• To replace electrostatic precipitator to fabric filter	350,000.00
Clinker Cooler	• To replace electrostatic precipitator to fabric filter	350,000.00
Raw Material Preparation	• Fully enclosed conveying system • Secondary containment for crusher act as collection of rocks/dust to be reuse	650,000.00
	Total Cost	4,300,000.00

The cost is estimated based on previous project in other plants in Malaysia own by the company. Some of the strategies has been implemented in the plant and the cost estimated is to increase the quantity such as the spraying water system, fully enclosed conveying extension and refurbish of the facilities. Total cost of these implementation is approximately RM 4.3 million.

Table 4.7: Financial evaluation on proposed strategies

Dust Generation	Before HBIDMS***			After HBIDMS***			
	Emission per annum (tonne)	Price* (RM)/kg	Cost (RM)	Reduction Factor**	Emission per annum (tonne)	Price* (RM)/kg	Cost (RM)
Quarry	704.00	0.36	253,440.00	0.90	70.40	0.36	25,344.00
Kiln Emission	540.00	0.36	194,400.00	0.95	27.00	0.36	9,720.00
Raw Material Processing	469.00	0.36	168,840.00	0.85	70.35	0.36	25,326.00
Cement Mill Grinding	259.00	0.36	93,240.00	0.90	25.90	0.36	9,324.00
Pre Heater	246.00	0.36	88,560.00	0.95	12.30	0.36	4,428.00
Clinker Cooler	211.00	0.36	75,960.00	0.85	31.65	0.36	11,394.00
Raw Material Preparation	199.00	0.36	71,640.00	0.85	29.85	0.36	10,746.00
Total Cost Estimated Before Implementation			**946,080.00**	Total Cost Estimated After Implementation			**96,282.00**

Note:
HBIDMS* ** - Hierarchical Based Integrated Dust Management System
Reduction factor** - was fairly based on the current dust control device efficiency and input from the plant process and environmental department.
Price * - Market price per bag of 50kg of cement is RM18 (RM18 /50kg = RM0.36/kg)

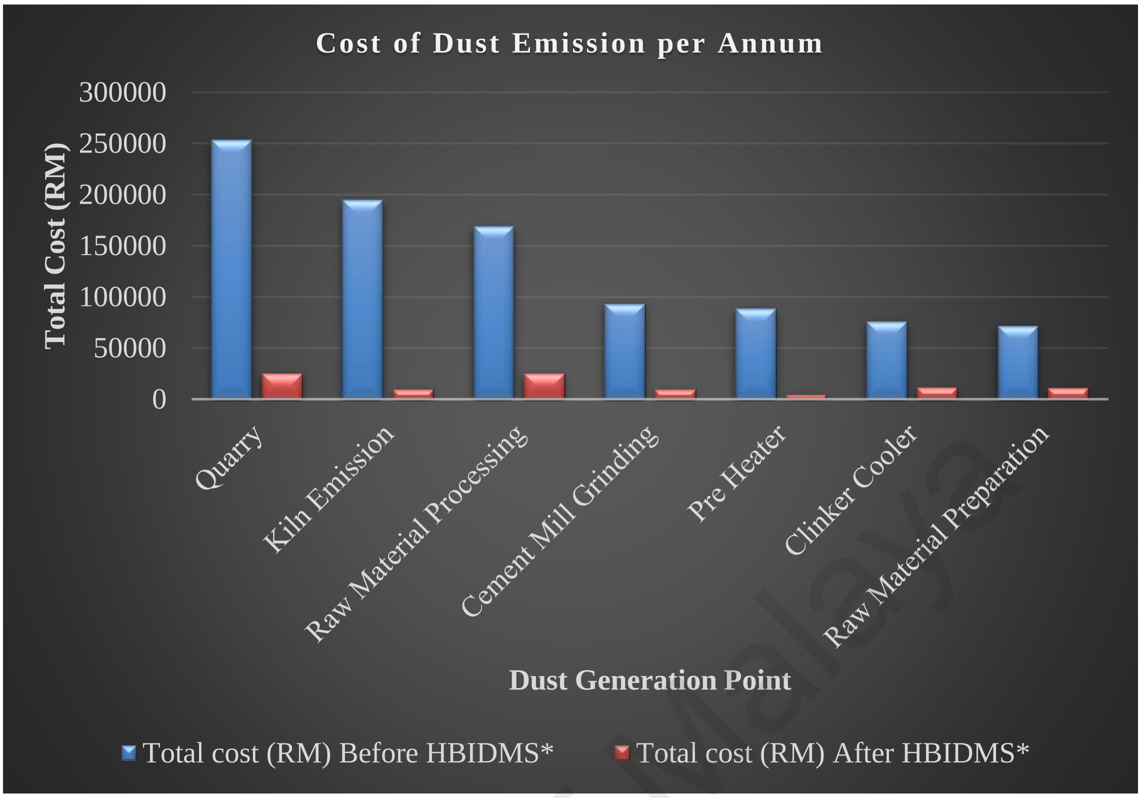

Figure 4.14: Cost of Dust Emission per Annum

The financial evaluation as shown in Figure 4.14, the bar chart illustrates the reduction of cost per annum in each process after the implementation of the hierarchical management strategies.

$$\text{Payback Period} = \frac{RM4{,}300{,}000}{RM(946{,}080-96282)}$$

$$= 5.06 \approx 5 \text{ years}$$

The payback period of this hierarchical based integrated dust management system is found to be in 5 years. The performance evaluation was done by stages by dust emission monitoring for point sources and ambient air quality check for fugitive dust. The emissions level for both dust sources found to be lower compared to before the implementation of HBIDMS proposed strategies. The plant visual inspection shows less dust deposition on the equipment and there was reduction on the equipment maintenance record.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Dust generated in cement plants poses environmental, safety and health problems for the not only the operators but also environment. Various dust control devices have been installed in cement plants to control dust pollution. Waste management hierarchy helps extracting the maximum practical benefits from products and generating the minimum amount of waste. This study concentrated on identifying dust generation sources and preventing dust generation by hierarchical integrated dust management system. The conclusions were drawn based on objectives, with the following information:

1. The sources, characteristic and possible risk of the dust generated in ABCD Sdn. Bhd. had been identified and presented in the form of table. Several sources of dust generation had been pointed out, namely quarrying, raw material processing, raw material preparation, mixing and blending, pre heater, kiln emission, clinker cooler, cement mill grinding, cement storage, packaging, and shipping. Characteristic and potential risk from the dust emitted was shown in the form of tables. The risk assessment done on the dust generation sources revealed that the highest priority of dust management required in quarry, kiln and raw material processing which has high impact rating.

2. Various strategies, technologies and control measure which can reduce the dust generation had been proposed in the study. The proposed control and prevent strategies focuses on the prevention of dust generation at the first place. In the event of prevention of dust generation impossible, plant can move on to emphasize on reduction, reuse and recovery of the dust before final disposal.

3. Finally the performance and financial evaluation on the selected proposed technology had been presented. From the evaluation done, it is made easier for one to choose better technology in relevant conditions.

5.2 Recommendation for future work

Based on the study done, it was possible to recommend that next study is done in with a more transparent non-disclosure agreement and involvement of the plant personnel to improve the results obtained. Cement manufacturing is a complicated process and requires an in depth study together with expertise involvement.

It is also recommended that future study is done in plant that are keen to use the model of waste management hierarchy where prevention of the dust generation is given priority instead of controlling of the dust generated. The proposed strategies take longer time to implement and plant need to agree as on-going production shall be affected.

Since the production of cement involves large area and number of processes, it is recommended that future study shall focus on a single process/equipment at a time to ensure the study can be done covering all objectives more completely.

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