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INHALABLE AND RESPIRABLE DUST FROM COAL-FIRED POWER PLANT

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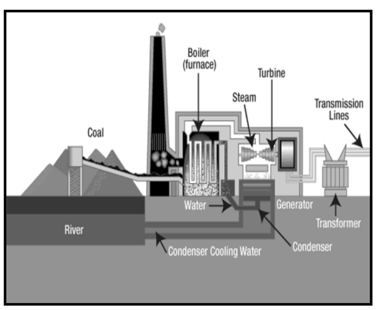
Graphical abstract



Abstract

Among the anthropogenic air pollutant that lead to the global warming, this research focuses on the inhalable dust and respirable dust that comes from the emissions of coal. Recently, the demand of electricity supply in Malaysiais raising and leads to the diversification of its resources towards the non-renewable energy. Coal-fired power plant emission had been recognized as one of the manmade sources of particulate matter. 8-hours personal particulate matter sampling had been done at a coal-fired power plant with 7-hole sampler at 2 L/min air flow and cyclone sampler at 2.2 L/min air flow. This study found that 96.78 % of the result from total inhalable dust exceeds the PM10DOE Malaysia standard of 0.15mg/m3. The percentage ratio of respirable towards total inhalable dust is 50.25%. Further analysis showed that as the temperature increases, the particulate matter concentration also increases. It is believed that the smaller particles offer higher degree of human health risk. The particulate from coal with aerodynamic diameter of 2.5 micron and lesser can be deposited into deeper part of lung and provide adverse health impact towards the public or residence of surrounding coal-fired power plant location area, generally and coal-fired power plant workers, in specific.

Keywords: Inhalable dust, respirable dust, power plant, human health, meterological factor

1.0 INTRODUCTION

The construction of the coal-fired power plant was decided to help Malaysia keep pace with its rapidly rising electricity demand. The country was experiencing high load of demand that required the addition of large amounts of base load electricity generating capacity. Whereas the power generation had always relied on gas in the past, the customer wanted to diversify the fuel, by choosing a coal-fired power plant.

The two main variables of this research are airborne particles and meteorological factor. Particulate matter (PM) is defined by US EPA [1] as a mixture of solid particles and liquid droplets found in the air. Thus, it is chosen as itaffects more people than any other type of pollutant.

The major components of PM are sulphate, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. The particles are identified according to their aerodynamic diameter as either fine particulate (PM2.5) particles with aerodynamic diameter equals to or smaller than 2.5 μm and ultra-fine particulate matter (PM1.0) is the subset of PM2.5 measuring less than 0.1μm in diameter [1,2]. The PM2.5 or also known as respirable dust is dangerous since, when inhaled, they may reach the peripheral regions of the bronchioles, and interfere with gas exchange inside the lungs that is the alveolar region [3]. Research found that the large difference of the physical size of particles is the effect of its aerodynamic properties formed by different materials. It also emphasizes that the size of dust particles generated by its individual materials and have their own biological effects.

2.0 RESEARCH PURPOSES

Facilities it is to be highlighted here that this research aims at assessing the particulate matter that is rooted from coal that disseminated by coal-fired power plant. Its objectives are to determine the particulate matter mass concentration contributed by the coal fired power plant, to establish the ratio of respirable to total inhalable dust contained in a contaminated sample and to identify the mass concentration changes affected by the temperature change.

3.0 PARTICULATE MATTER IN COAL

3.1 Pollution Issues of a Coal-Fired Power Station

The plant uses low sulphur and low bitumen coal (pulverized for burning) to minimize pollution. The resulting ash is valuable for the cement industry, and most of it is caught by electrostatic precipitators. Dust control is also an important feature (the conveyor belt is covered and sprinkler systems removed up to 99.9%).

The plant has a wastewater treatment facility to treat its effluent before it is released into the sea. The project even includes a plan to reinvigorate decayed mango swamps in the area. The plant will meet far higher emission standards than other ASEAN powerplant. It operates to particulate levels of 50 mg/Nm³ whilst the expected ASEAN level is 400 mg/Nm³. The plant uses low NOx burners and a flue gas desulphurization facility to keep NOx and SOx emissions low [4].

3.2 Coal Fired Power Plant

The power plant selected for the purpose of this study is a pulverized coal firing type that contains 2,295 MW capacities [5] and has been operating since September 2002. This coal-fired power plant is sited on a man-made island off the coast of the country that is 4.5 m above mean sea level. It is located 10 km of the south of the nearest town Lumut, approximately 288 km north of the city centre of the country and close to the tourist island [4]. Populations are at 211,113 numbers of people. While the domestic visitors number are 448,646 numbers of people and foreign visitors at 234,964 numbers of people. Hence, the temporary health impact of airborne particulate affects the visitors while the permanent health impact affects the town residents. This state is known as the high humidity area. March and July are both in dry season. However, March occupied higher temperature and lower humidity than July.

Burning coal in a power plant produces a number of pollutants. Some of these pollutants are specific to the type of fuel or is part of the combustion process or related to the design and configuration of the plant. The highlighted major pollutants discharged from the power plant are carbon dioxide, sulphur dioxide, ash, particulate matter and nitrogen oxides.

3.2.1 Carbon Dioxide(CO_2)

CO_2 was thought of as a product of combustion and not as a pollutant. Kyoto protocol, effects of Green House gases and global warming issues have changed the way we look at CO_2. CO_2 has turned to be the major greenhouse gas. A fossil fuel power plant is the major contributor of CO_2. One MJ of heat input produces 0.1 kg of CO_2. The only way to eliminate CO_2 is to capture it before leaving to atmosphere. After capturing it has to be stored permanently or sequestered. Commercially viable capture and sequestration systems are yet to be in place. Till such time the only way is to:-

i) Improve the power plant efficiency so that the reduced coal consumption reduces CO_2 per kWh.

ii) Switch over from fossil based energy sources to renewable sources like wind, solar or hydropower.

iii) Reduce deforestation and increase afforestation to absorb the excess CO_2 produced.

3.2.1 Sulphur Dioxides (SO2)

This is a product of combustion and depends on the amount of sulphur in coal. This is also referred to as So_x. Sulphur in coal ranges for 0.1 % to 3.5% depending on type and rank. During combustion sulphur combines with oxygen to form SO_2. Power plants are the largest emitters of SO_2. In the presence of other gases SO_2 forms sulphuric acid and can precipitate down as acid rain leading to destruction of eco systems. Use of low sulphur coals is the best ways to reduce the SO_2 emissions. Desulphurization plants downstream of the boilers also reduce emissions. Fluidized bed combustion of coal is another effective method to reduce SO_2 emissions.

3.2.3 Ash

Ash is the residue after the combustion. A 500 MW coal fired power plant burning coal with around 20 % ash, collects ash to the tune of two million tons in five years.

Cement plants may utilize a small portion of the ash. Disposing bulk of it on a long-term basis can raise major environmental issues.

i) Ash contains toxic elements that can percolate into the drinking water system.

ii) The wind, breach of dykes or ash spills can carry away the ash particles to surrounding areas causing harm to humans and vegetation.

Considering the life of a power plant is 20 years, great foresight, planning and commitment is required to dispose the ash in an eco-friendly way.

3.2.4 Inhalable and Respirable Dusts

Power plants have elaborate arrangements to collect the ash. A small quantity still goes out through the stack and is categorized as airborne particles emission. The very tall stacks in power plants disperse this ash over a very wide area reducing the concentration levels to human acceptable levels at ground levels. For the coal inhalable and respirable dusts, it comes through the combustion process thus grouped under the category of fine and ultrafine particles as indicated by the CAI- Asia Centre [6] and Masitah Alias *et al*., [7]. The particles of size less than 2.5 μm ($PM_{2.5}$) is of great concern since these are responsible for respiratory illness in humans. As described by ISO 7708: 1995 [8], the respirable fraction is the mass fraction of inhaled particles which penetrate to the unsolicited airways extending from the respiratory bronchioles to the alveoli. This type of airborne particles sampling is done in order to acknowledge the risk faced by the high risk groups that are children, sick and infirm. Thus, the following Figure 1 illustrated the "high risk" respirable convention where the airborne particles pollution is at minimal size of 7.07 μm as mentioned by Morawska and Salthammer [9] and supported by Shamzani and Normadihah [10]. This contributes to high risk towards the human health. These include both fine and ultrafine particulate matter emitted by coal-fired power plant.

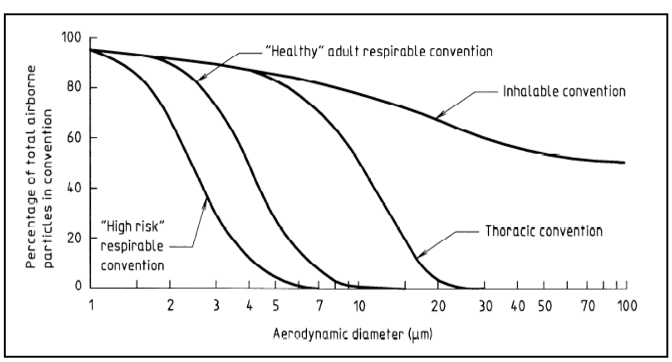


Figure 1 The Inhalable, Thoracic and Respirable Conventions Expressed as Percentages of Total Airborne Particles [10]

3.2.5 Nitrogen Oxides(NOx)

Nitrogen in fuel and in the air reacts with Oxygen at high temperatures to form various oxides of Nitrogen collectively called NO_X. Fossil fuel power plants are the second largest emitter of NO_X. This is a hazardous pollutant creating visual and respiratory problems. Also NO_X combines with water to form acid rain, smog, and ground ozone. Design changes in combustion technology have helped in reducing the NO_X emissions. Methods like Selective Catalytic Reactors are used in power plants to meet the emission regulations.

3.2.6 Coal Particulate

Burning coals in a power plant produces a number of pollutants. It comes from the fuel type; combustion process; and design and configuration of the plant. The pollutants that contaminate the ambient from coal power plant are carbon dioxide (CO_2), sulphur dioxide (SO_2), ash, particulate matter and nitrogen oxides (NOx) are being recognised as the air pollutants that emitted from the coal-fired power plants.

Although the power plants management includes the arrangements to collect the ash, but the airborne particles are still emitted to the air through the stack. It is understood that the very tall stacks in power plant emit this ash throughout the area reducing the concentration levels to human acceptable levels on the ground plane.

In order to reduce atmospheric pollution, the management of this coal-fired power plant decided to use low sulphur and low bitumen coal that are beneficial for cement industry. Therefore, the plant uses low NOx burners and a flue gas desulphurization facility. Dust control, the conveyor belt is covered and sprinkler systems removed up to 99.9% and electrostatic precipitators are important features for this factor.

Before the waste is being deposited into the sea, it is being treated by wastewater treatment facility [1, 2, 3, 4 and 5]. In addition, this power plant is designed to meet far higher emission standards than would be typical for an ASEAN country. It operates to particulate levels of 50mg/Nm³ that is lower than the expected ASEAN level of 400mg/Nm³ [3, 4].

Burning coal in a power plant, as illustrated in Figure 2, produces a number of pollutants. It comes from the fuel type; combustion process; and design and configuration of the plant. The pollutants that contaminate the ambient from coal power plant are carbon dioxide (CO_2), sulphur dioxide (SO_2), ash, particulate matter and nitrogen oxides (NOx) are recognised as the air pollutants emitted from the coal-fired power plant.

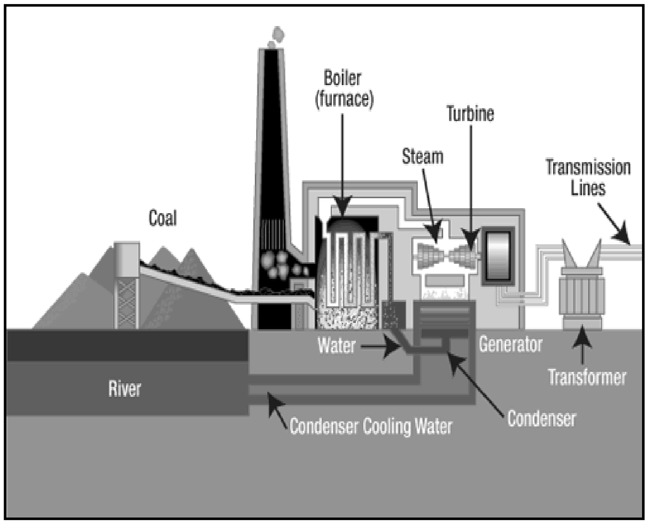


Figure 2 Coal Fired Thermal Power Plant: The Basic Steps and Facts [11]

4.0 RESEARCH METHODOLOGY

This research combined both qualitative and quantitative research methodology. Literatures of primary and secondary sources are being reviewed. The research technique applied includes the inhalable and respirable 8-hours air sampling using Casella 7-hole sampler at 2.0L/min air flow and SKC cyclone sampler at 2.2 L/min air flow, accordingly. The inhalable dusts were collected by using the 7-hole sampler. It is small particulate that are larger than 2.5µm diameter and smaller than 10µm in diameter. However, the respirable dusts were collected by using the cyclone sampler. It is small particulate that are smaller than 2.5µm diameter. The mass concentrations were then obtained by adopting the following formula:-

Mass concentration = Filter Paper Weight after- Weight before (mg)
 1 m³ x Flow Rate x Duration of sampling (min)
1000L min

Later, statistical approach was used to analyse the attained data. The graphs are plotted and analysed by comparing with the US EPA 24-hour standard of $PM_{2.5}$ at 0.35mg/m³ and Malaysian Department of Environment of PM_{10} 24-hour standard at 0.15mg/m³.

5.0 RESEARCH ANALYSIS AND DISCUSSION

This research found that for the case study coal-fired power plant, total inhalable dust exceeds 96.78 % while 5.33% below the PM_{10} standard of 0.15mg/m³. As indicated in the bar chart in Figure 3, none of the result exceeds the US EPA $PM_{2.5}$ standard of 0.35mg/m³. However, it is to be highlighted here that the March and July personal particulate matter samplings are conducted for eight hours. The result shows that the March result of total inhalable dust exceeded 11.44 % of Malaysia PM_{10} standard, while in the July exceeded at 80%. Thus, in average the total inhalable dust exceeded 96.78 % of Malaysia PM_{10} standard. Moreover, it is also found that the July result shows that the total inhalable dust exceeded at 9.24% from the US EPA $PM_{2.5}$ standard. Thus, it can be concluded that the mass concentration level of coal-fired power plant at this case study area is high and may cause adverse health impact towards human being. This is as supported by the London Smog tragedy that occurred in 1952 [12-13]. It is to be highlighted that the coal particulate causes health impact toward respiratory, cardiovascular and nervous system.

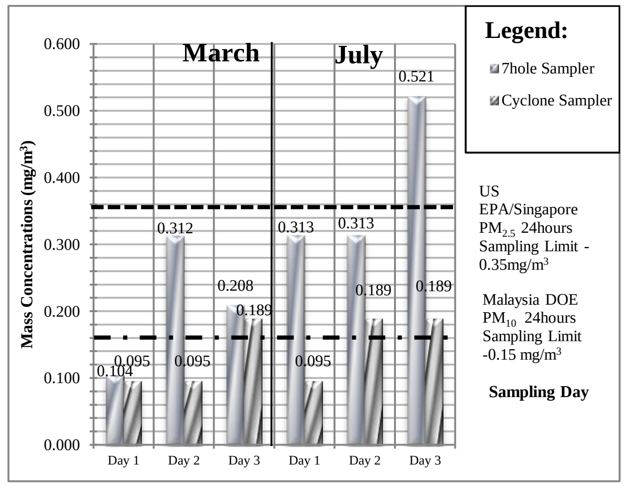


Figure 3 Comparison $PM_{2.5}$ and $PM_{0.1\text{-}1.0}$ Mass Concentration

This research also found that the average percentage ratio of respirable towards inhalable dust is 40.87% in March while 58.64% in July. Thus, aver aging at 50.25%. This is clearly illustrated in Figure 4 below. It can be seen that the percentage of respirable dust of this coal-fired power plant is more than half than the inhalable dust. Hence, explaining that it is still at a critical level. This is due to the fact that the smaller particle deposited into deeper lung and causes higher risk towards human health. Referring to the Figure 2 of ISO convention, this type of PM affects the high-risk people that include children, sick and infant.

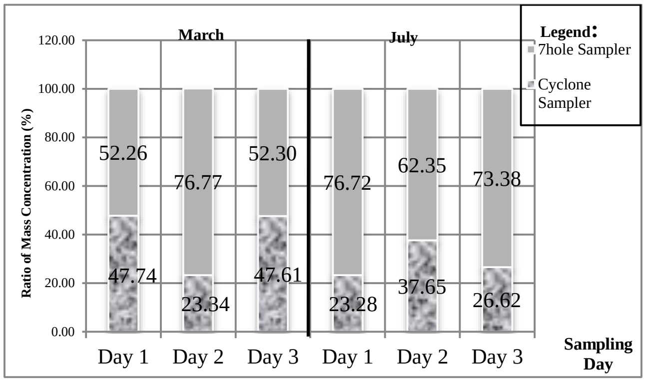


Figure 4 Ratio of Mass Concentration Total Inhalable Dust vs. Respirable Dust sampling

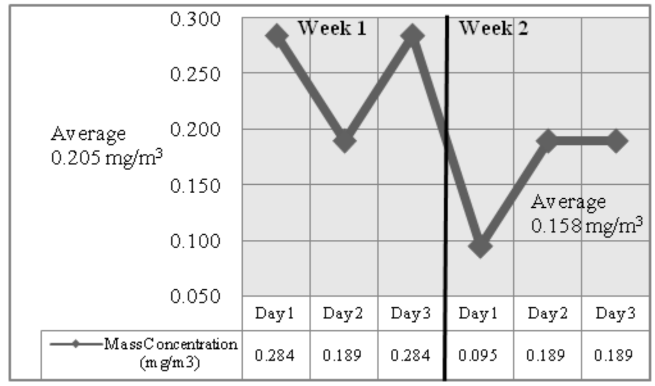


Figure 6 Mass Concentration of Respirable Dust of sampling on Week 1 and Week 2

Furthermore, it is found that as the average temperature decreased from week 1 at 30.87 degree Celcius (°C) to 30.07°C, the particulate matter concentration also decreased from 0.252 to 0.158 mg/m^3. As the temperature decreased 2.59%, the mass concentration of the particulate matter also decreased at 37.52%. This is demonstrated in the following Figure 5 and Figure 6. Thus, it is believed that weather and climate factor affect the amount of airborne particles disseminated to the atmosphere and ground. Hence, supporting the Aleksandropoulou and Lazaridis [14] theory that the summer season offers dry meteorological condition that favours the occurrence of dust transport events over the area.

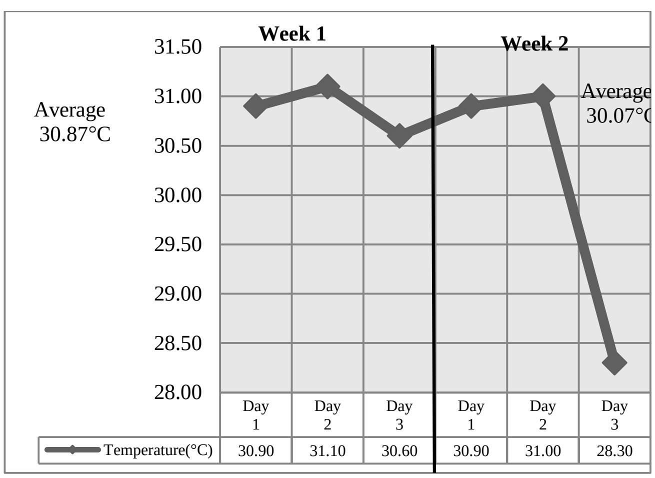


Figure 5 Temperature variations in Week 1 and Week 2

Moreover, the case study state faced high rainfall density. However, the samples were collected in March during which the temperature was high and the humidity was low; and in July when the temperature was low and the humidity was high. This is supported by Jacobson [15] that the ground surface temperatures affect the mixing depths and pollution mixing ratios. Hence, the warm ground is found to produce high inversion base heights and resultant into low pollution mixing ratios which are in contrast to the cold grounds surfaces that produce thin mixing depths and high pollution mixing ratios.

6.0 CONCLUSION

Climate change, as a result of coal being the source of electrical supply, leads to high concentration of inhalable dust and respirable dust to the atmosphere. Moreover, it is also found that hot weather affects the temperature of ground that later affect the thick mixing depth and low mixing ratio of the particulate matter. These later provide adverse health impact towards human. It is recommended to revise the standard of particulate matter that is practiced in Malaysia suitable to the Malaysian weather condition. Another approach is to develop standard specifically for particulate matter and other air pollutant emitted from electrical power stations. Other alternative to produce electricity from clean, safe and renewable sources should also be reviewed.

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