Jurnal
Teknologi

Full Paper

COAL-FIRED POWER PLANT AIRBORNE PARTICLES IMPACT TOWARDS HUMAN HEALTH

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Article history
Received
5 August 2015
Received in revised form
21 November 2015
Accepted
28 November 2015

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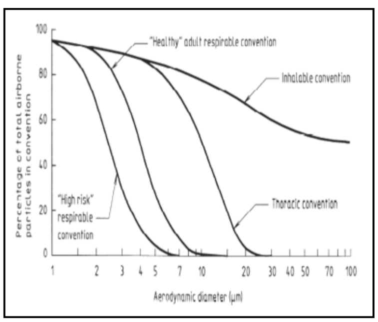
Graphical abstract



Abstract

The explosion of global warming and climate change occurs parallel to the raise rise of earth development. These phenomena happen due to the deterioration of atmospheric environment rooted from human activity. Ranges of air pollutants had been discovered. However, this research focuses on airborne particles in particular that comes from the emissions of coal. Recently, Malaysia electricity demand is raising and leads to the diversification of its sources towards the non-renewable energy. Manjung coal-fired power plant emission had been recognised as one of the potential anthropogenic sources of airborne particles. 8-hours airborne particles sampling had been done at Manjung Power Plant in March and July 2011 with 7-hole sampler at 2 L/min air flow and cyclone sampler at 2.2 L/min airflow. This research found that total inhalable dust exceeds 96.78 %; PM10 standard of 0.15mg/m^3.This study also found that the percentage ratio of respirable towards total inhalable dust is 33.49%. This study also found that, as the temperature increases, the airborne particles concentration also increases. It is believed that the smaller offers particulate higher degree of illness. Thus, it is believed, the airborne particles dissemination from its sources is affected by the climate of an environment. Whichcan be deposited into deeper part of lung and provide adverse health impact towards the public or residence of surrounding coal-fired power plant neighbourhood area, generally and coal workers, specifically.

Keywords: Airborne particles, coal, power plant, human health

1.0 INTRODUCTION

The construction of the Manjung 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 [1].

The two main variables of this research are airborne particles and human health. PM is defined as a mixture of solid particles and liquid droplets found in the air [2]. Thus, it is chosen as it affected 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 particulates ($PM_{2.5}$)particles with aerodynamic diameter equals to or smaller than 2.5 μm and ultra fine particulate matter ($PM_{1.0}$) is the subset of $PM_{2.5}$ measuring less than 1.0 μm in diameter [2; 3]. The $PM_{2.5}$ or also known as respirabledustis 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 [4].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

It is to be highlighted here that this research aims at assessing the airborne particles that is rooted from coal that disseminated by coal-fired power plant and its effect towards human health.Its objectives are to determine the airborne particles mass concentration contributed by the coal fired power plant, to compare the amount of respirable and total inhalable dust contained in a contaminated sample and to identify the mass concentration changes affected by the temperature change.

3.0 AIRBORNE PARTICLES IN COAL

3.1 Pollution Issues of Manjung 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 waste water 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 power plant. 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 [1; 5].

4.0 MANJUNG COAL FIRED POWER PLANT

Manjung power station is a pulverized coal firing type that contain 2,295 MW capacity [6] and has been operating since September 2002. Currently, it is managed by the TNB Jana Manjung Sdn Bhd.

The Manjung coal-fired power plant is sited on a man-made island off the coast of Perak, Malaysia, 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 Kuala Lumpur and close to the tourist island of Pangkor [5]. 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 particle affects the visitors while the permanent health impact affected the Manjung residents. Perak 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, airborne particles and nitrogen oxides.

4.1 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 kWhr.
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.

4.2 Sulphur Dioxide (SO_2)

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 Sulfur 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.

4.3 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.

4.4 Airborne Particles

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 airborne particles, it comes through the combustion process thus grouped under the category of fine and ultrafine particulates matter as indicated by [6] and [7]. The particles of size less than 2.5 µm called $PM_{2.5}$ is of great concern since these are responsible for respiratory illness in humans. As described by [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 particulates sampling is done in order to acknowledge the risk faced by the high risk group that are children, sick and infirm. Thus, the following Figure 1 describes the "high risk" respirable convention where the particulates pollution is at minimal size of 7.07 µm as mentioned by [9] and supported by [10]. This contributes to high risk towards the human health. These include both fine and ultrafine particulates emitted by coal-fired power plant.

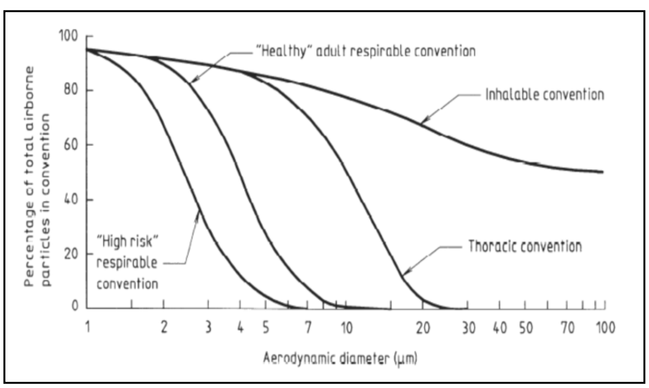


Figure 1 The Inhalable, Thoracic And Respirable Conventions Expressed As Percentages Of Total Airborne Particles. Morawska. L and Salthammer. T (2004) in Shamzani and Normadihah (9), [10]

4.5 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.

4.6 Coal Particulate

Burning Coal 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, airborne particles and nitrogen oxides (NOx) are being recognised as the air pollutants that emitted from the coal-fired power plant

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 [1].

In order to reduce atmospheric pollution, Manjung power plant uses 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; 5]. In addition, Manjung 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. [4; 5].

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, airborne particles and nitrogen oxides (NOx) are recognised as the air pollutants emitted from the coal-fired power plant.

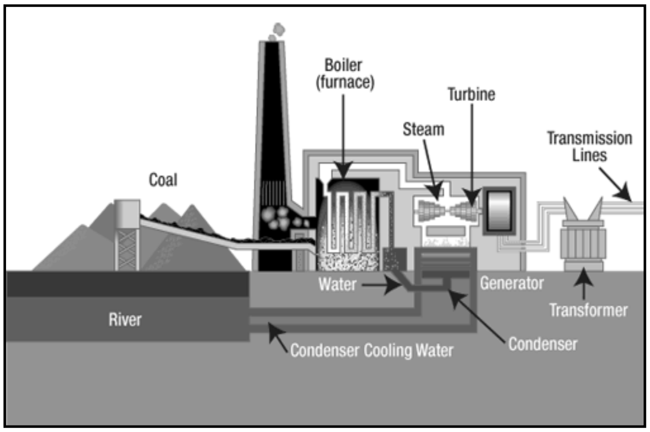


Figure 2 Coal Fired Thermal Power Plant: The Basic Steps and Facts, Johnzactruba (15)

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5.0 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 particulates 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 particulates that are smaller than 2.5µm diameter. The mass concentrations were then obtained by adopting the following formula:

$$\text{Mass concentration} = \frac{\text{Filter Paper Weight after- Weight before (mg)}}{\frac{1\ m^3}{1000L} \times \frac{\text{Flow Rate}}{\text{min}} \times \text{Duration of sampling (min)}}$$

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.

6.0 RESEARCH ANALYSIS AND DISCUSSION

This research found that for Manjung Power Plant, total inhalable dust exceeds 96.78%; while respirable dusts exceeded 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.

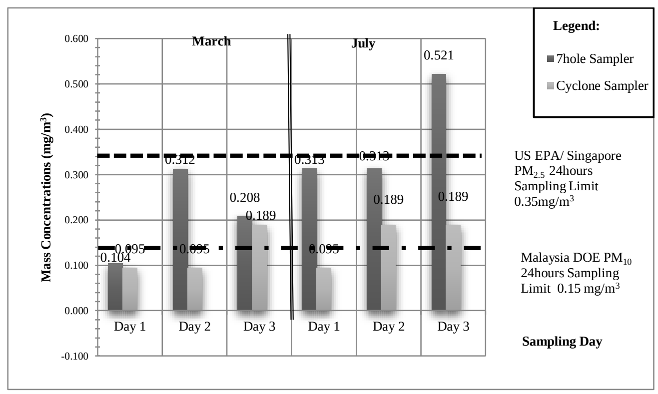

Figure 3 Comparison Manjung $PM_{2.5}$ and $PM_{1.0\&1.0}$ Mass Concentration between March and July 2011

However, it is to be highlighted here that the March and July 2011 airborne particulate samplings are conducted for eight (8) 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 in Manjung is high and may cause adverse health impact towards human being. This is as supported by the London Smog tragedy that occurred in 1952 [11] and [12] highlighted that the coal particulates cause health impact toward respiratory, cardiovascular and nervous system.

The study in Manjung found that the average percentage ratio of respirable towards inhalable dust is 37.79% in March while in July is at 29.20%.The average percentage ratio of respirable towards inhalable dust is34.37%. This is clearly illustrated in Figure 4 below. It can be seen that the percentage of respirable dust of Manjung coal-fired power plant is more than a quarter of the inhalable dust. Hence, explaining that it is still at a good level but must take certain precaution action. 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 infirm.

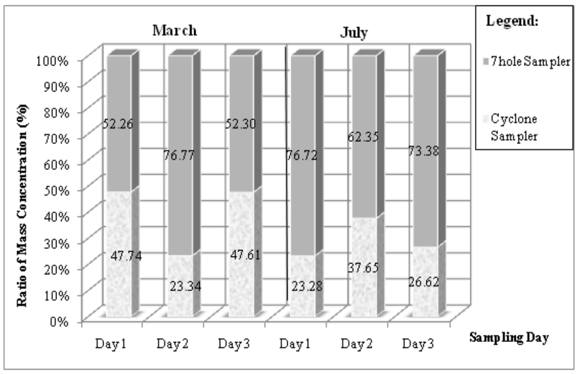

Figure 4 Ratio of Mass Concentration Total Inhalable Dust vs Respirable Dust sampling at Manjung in March and July 2011

Furthermore, it is found that as the average temperature decreased from 30.87 degree Celsius (°C) to 30.07 °C, the airborne particles concentration also decreased from 0.252 to 0.158 mg/m^3. As the temperature decreased 2.59%, the mass concentration of the airborne particles 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 particulates disseminated to the atmosphere and ground. Hence, supporting the [13] theory that the summer season offers dry meteorological condition that favors the occurrence of dust transport events over the area.

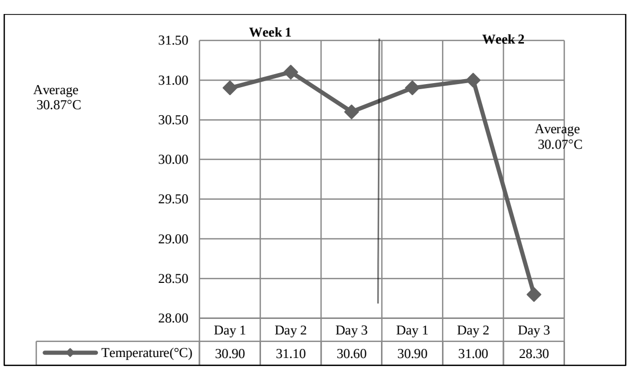

Figure 5 Temperature on Week 1 and Week 2 in March 2011, at Manjung

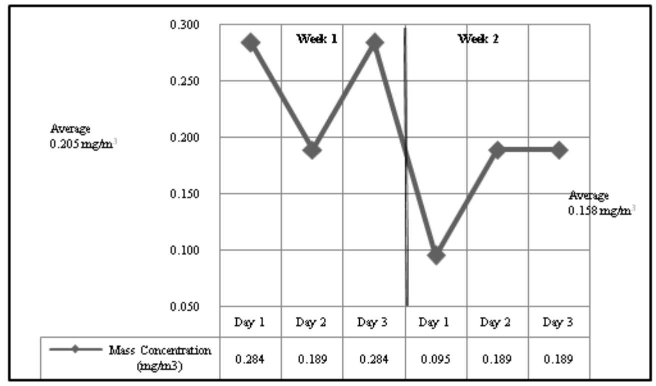

Figure 6 Mass Concentration of Respirable Dust of sampling on Week 1 and Week 2 in March 2011, at Manjung

Moreover, Perak 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 [14] 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 is in contrast to the cold grounds surfaces that produce thin mixing depths and high pollution mixing ratios.

7.0 CONCLUSION

Climate change, as a result of coal being the source of electrical supply, leads to high emissions of fine airborne particles to the atmosphere. Moreover, it is also found that hot weather causes the dispersion of plumes from the stack at higher level. These later provide adverse health impact towards human directly or indirectly, and with short term or long-term exposure. It is recommended to revise the standard of airborne particles that is practiced in Malaysia aligned with the Malaysian weather condition. Another approach is to develop standard specifically for airborne particles and other air pollutant emitted from electrical generation. Other alternative to produce electricity from clean, safe and renewable sources should also be reviewed.

Acknowledgement

Greatest appreciation to Research Management Centre (RMC), International Islamic University of Malaysia (IIUM) and Ministry of Higher Education (MOHE) for the funding assistant of this research with the grant no. RAGS12-043-0043 and IIUM Endowment grant no. EDW B13-045-0930.

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