PM_{10} AND TOTAL SUSPENDED PARTICULATES (TSP) MEASUREMENTS IN VARIOUS POWER STATIONS

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Key words: Particulate matter, total suspended particulate, personal dust, PM_{10}.

Abstract

The quality of air that we breathe in every second determine by the amount of particulate matter in it. These particulate matters measure by their particles size. Those with the particles size less than 10 micron (PM_{10}) is used to monitor the air quality which in turn is related to the health problems of the workers or public at large. The amount of PM_{10} is related to the amount of total suspended particulates (TSP) in the air. The amount of air particulates in the air was measured using a personal dust monitor. In this study, the focus is on measurement of air particulates namely PM_{10}, and TSP measured in TNB Research, Connaught Bridge Repair Shop, JPS Kapar, and Port Dickson Power Stations. PM_{10} and TSP was measured using mini volume sampler, and as comparison, personal dust was measured using personal dust sampler. The choice of sampling locations in each place is based on the source of air particulates to be measured. The results obtained for PM_{10} are in the ranges of 42.4 – 108.3 ug/m^3, 88.8 – 103.5 ug/m^3, 42.1 – 69.3 ug/m^3, 35.31 – 196.86 ug/m^3 and 35.71 – 428.57 ug/m^3 for Connaught Bridge Repair Shop (indoor), PD Power Station (outdoor), TNB Research (indoor and outdoor) and JPS Kapar (indoor and outdoor) respectively. These values are compared to the Malaysian air quality guideline for PM_{10} set at 150 μg/m^3 and total suspended particulates (TSP) set at 260 μg/m^3.

Abstrak

Kualiti udara yang kita sedut setiap saat ditentukan oleh jumlah zarah pepejal di dalamnya. Zarah pepejal ini ditentukan melalui saiznya. Zarah pepejal dengan saiz kurang dari 10 micron (PM_{10}) digunakan untuk mengesan kualiti udara dimana ia berhubung kait dengan masalah kesihatan pekerja mahu pun orang awam. Jumlah PM_{10} adalah berkadaran dengan jumlah pepejal terampai (TSP) di udara. Jumlah zarah pepejal di udara telah di ukur menggunakan pengesan debu peribadi. Di dalam kajian ini, fokus adalah kepada pengukuran zarah pepejal PM_{10} dan TSP yang dijalankan di TNB Research, JPS Connaught Bridge, JPS Kapar, and Stesen Janakuasa Port Dickson. PM_{10} dan TSP telah di ukur menggunakan penyampel isipadu kecil dan dibandingkan dengan pengesan debu peribadi. Pemilihan lokasi persampelan adalah berdasarkan jenis kerja-kerja yang dijalankan dan punca zarah pepejal. Keputusan yang diperolehi untuk PM_{10} adalah di dalam julat 42.4 – 108.3 ug/m^3, 88.8 – 103.5 ug/m^3, 42.1 – 69.3 ug/m^3, 35.31 – 196.86 ug/m^3 dan 35.71 – 428.57 ug/m^3 untuk JPS Connaught Bridge (dalam), Stesen Janakuasa Port Dickson (luar), TNB Research (luar dan dalam) dan JPS Kapar (luar dan dalam) masing-masing. Nilai ini kemudiannya dibandingkan dengan Malaysian air quality guideline dimana untuk PM_{10} adalah 150 μg/m^3 dan TSP adalah 260 μg/m^3.

Introduction

The air we breathe is a mixture of gases and small solid and liquid particles. Some substances come from natural sources while others are caused by human activities such as our use of motor vehicles, domestic activities, industry and business. Air pollution occurs when the air contains substances in quantities that could harm the comfort or health of humans and animals, or could damage plants and materials. These substances are called air pollutants and can be either particles, liquids or gaseous in nature [1].

Not all air pollutants are gases. ***Particulate matter (PM)*** is a collective term used for very small solid and/or liquid particles found in the atmosphere. While individual particles cannot be seen with the naked eye, collectively they can appear as black soot, dust clouds or grey hazes. Particulate matter may be generated by natural processes (e.g., pollen, bacteria, viruses, fungi, mold, yeast, salt spray, soil from erosion) or through human activities, including diesel trucks, power plants, wood stoves and industrial processes. Individual particles vary considerably in size, geometry, chemical composition and physical properties. The effect of particulates on human health and the environment varies with the physical and chemical makeup of the particulates. Particles are either emitted directly into the atmosphere or produced in the atmosphere from the physical and chemical transformation of other vaporous or gaseous pollutants [2].

Total suspended particulate (TSP) refers to all particles in the atmosphere. TSP was the first indicator used to represent suspended particles in the ambient air. In July 1987, United State Environmental Protection Agency (USEPA) began using a new indicator, PM_{10}, which includes only those particles with aerodynamic diameter smaller than 10 μm. Ten microns is approximately one seventh the diameter of a human hair. This fraction of TSP is responsible for most of the adverse human health effects of particulate matter because of the particles' ability to reach the lower regions of the respiratory tract. Recent data suggests that particles of 2.5 um or smaller may pose the greatest threat to human health because, for the same mass, they absorb more toxic and carcinogenic compounds than larger particles and penetrate more easily deep into the lungs. USEPA is considering adopting a new standard for $PM_{2.5}$ to better address the potential health problems associated with these tiny particles.

The major sources of atmospheric particulates are fossil-fuel combustion (which produces ash and soot), industrial processes (involving metals, fibers, etc.), transportation, wind and soil erosion (producing fugitive dust), and photochemical reactions (complex chain reactions between sunlight and gaseous pollutants). Fugitive dust and particles from industrial processes tend to be larger in size (> 1 um). Particles from combustion and photochemical reactions are usually smaller in size (< 1 um).

Because of the large number of sources, particulate matter may contain hundreds of different chemical elements. Fine particles (PM_{10}) may contain substantial quantities of sulfate, ammonium, nitrate, elemental carbon and condensed organic compounds. Carcinogenic compounds and heavy metals such as arsenic, selenium, cadmium and zinc are also concentrated in these particles. Larger particles, such as soil particles, fly ash, road aggregate, wood ash, soot and pollen are composed primarily of minerals, including silicon, aluminum, potassium, iron, calcium and other alkaline elements [3, 4, 5].

Various plants in this country such as power plant and repair shops related to power plant contributed to some extend the air particulate matters to the surrounding environment. This contribution more or less affects the air quality of those respected area. Objectives of this study are to measure the TSP and PM_{10} air particulates in the selected areas namely power plant and repair shops related to power p lant, to study the distribution profile of the air particulates content and to evaluate its possible health risk to the workers who spent most of their lifetime in those places.

Method

Sampling and Sample Preparation

Affordable and portable, the Mini Volume Portable Air Sampler samples air at 5 liters/minute for particulate matter (TSP and PM_{10}) measured at 1 meter height above the ground. The mini volume features an elapsed time totalizer, a programmable timer, low flow and low battery shut-offs, operation from rechargeable batteries, and rugged PVC construction. The filter holder assembly can be configured for TSP, PM_{10}, or $PM_{2.5}$ sampling, and a mini volume with gas ability can sample for non-reactive gases simultaneously while sampling for particulate matter. Particle size separation is achieved through impaction. The particulate matter is collected on 47 mm Teflon filters, which must be weighed pre- and post-exposure to determine concentrations in micrograms/cubic meter. Connaught Bridge Repair Shop, Kapar Repair Shop, TNB Research and Port Dickson Power Station were chosen as the locations for this study. TSP and PM_{10} measurements were done for 24 hours [6].

Measurement

The exposed filters were brought back to the lab and kept in a desiccator's for 24 hours to ensure no moisture effect on the air particulate weight. The filter was weighed using semi -micro balance.

Data Analysis

To calculate the TSP and PM_{10} concentration for a sample taken with the Mini Volume sampler, the volume of air that passed through the filter at standard conditions, V_{std} or at emission condition, V_{act}, must be calculated. This is most easily done in a multi steps procedure.

P_{act} average (mmHg) = 754.6

T_{act} average (34 ^{0}C) = 307K

The gross masses of particulate matter on the sample filter (W_g):

F_e: Weight after sampling;

F_c: Weight before sampling

$W_g = F_e - F_c$

Air flow rate at ambient conditions

Q_{act} (L/min) = $(m_{vol} \times Q_{ind} + b_{vol}) \times (P_{std}/Pact_{avg} \times Tact_{avg}/T_{std})^{½}$ (1)

Sample air volume (V_{act}) in m^3 at actual conditions

V_{act} (m^3) = 0.001 m^3/L x Q_{act} L/min x t min (2)

Sample air volume (V_{std}) in m^3 at standard conditions (25°C & 760mmHg)

V_{std} (m^3) = $V_{act} \times (P_{act}/P_{std})(T_{std}/T_{act})$ (3)

Total Suspended Particulate/PM_{10} concentrations in ug/m^3 at standard condition (25°C & 760 mmHg)

PM_{10} (ug/m^3) = 1000 x 1000 x W_g/V_{std} (4)

Results

Table 1 show results of air particulates concentration collected from a few locations in Connaught Bridge Repair Shop. Table 2 show results of air particulates concentrations measured at Port Dickson Power Station. Table 3 show results of air particulates concentrations measured at TNB Research, Bangi. Table 4 show results for Kapar Repair Shop measured inside and outside of the building.

Table 1: Results of PM_{10} and TSP Measured at Connaught Bridge Repair Shop

Sampling area	**Suspended Particles (ug/m³)**	
	PM_{10}	**TSP**
Blasting (in)	108.3	216.6
Blasting (out)	94.1	188.2
Welding	86.5	144.0
Fitting (in)	56.5	113.0
Fitting (out)	42.4	84.6
Grinding (in)	100.5	167.5
Grinding (out)	24.1	41.2
Corridor	55.7	111.4
Maintenance	52.9	105.8
VBM Area	57.6	115.2
Range	**42.4 – 108.3**	**41.2 – 216.6**

Table 2: Suspended particulates measured at Port Dickson Power Station

Sampling area	**Suspended Particulates (ug/m³)**	
	PM_{10}	**TSP**
Roof top	88.8	177.6
Near construction entrance	103.5	207.0
Range	**88.8 – 103.5**	**177.6 – 207.0**

Table 3: PM_{10} and TSP measured at TNB Research, Bangi.

Sampling area	**Total Suspended Particulates (ug/m³)**	
	PM 10	**TSP**
Open space (field)	56.2	98.3
Badminton Court	42.1	56.2
ETAC	41.9	65.9
Canteen	69.3	112.1
Kindergarten	43.2	71.9
Range	**42.1 – 69.3**	**56.2 – 112.1**

Table 4: Kapar Repair Shop (inside & outside building)

Location	TSP (mg/m^3) (outdoor)	PM_{10} (mg/m^3) (outdoor)	Location	TSP (mg/m^3) (indoor)	PM_{10} (mg/m^3) (indoor)
V1	185.71	111.43	P1	119.04	71.42
V2	247.14	148.28	P2	59.52	35.71
V1	213.67	128.2	P1	**595.24**	**355.74**
V2	**328.10**	**196.86**	P2	**714.29**	**428.57**
V1	154.27	92.56	P1	119.04	71.42
V2	169.97	101.98	P2	**297.61**	**178.57**
V1	139.47	83.68	P1	178.57	107.14
V2	125.52	35.31	P2	**297.61**	**178.57**
V1	105.93	52.97	P1	148.80	89.28
V2	148.30	74.15	P2	119.04	71.42
Range	**105.93 – 328.1**	**35.31 – 196.86**	**Range**	**59.52 – 714. 29**	**35.71 – 428.57**

Source: Report on dust and fly ash monitoring for JPS Kapar, by Hamidah Sakeh.

Discussion

Connaught Bridge Repair Shop recorded the range of 42.4 – 108.3 and 41.2 – 216.6 ug/m^3 for PM_{10} and TSP measurements respectively. Port Dickson Power Station recorded the range of 88.8 – 103.5 and 177.6 – 207.0 ug/m^3 for PM_{10} and TSP measurements respectively. TNB Research recorded the range of 42.1 – 69.3 and 56.2 – 112.1 ug/m^3 for PM_{10} and TSP measurements respectively. Kapar Repair Shop recorded the range of 35.71 – 428.57 and 59.52 – 714.29 ug/m^3 of PM_{10} and TSP for indoor measurements and 35.31 – 196.86 and 105.93 – 328.1 ug/m^3 of PM_{10} and TSP for outdoor measurements.

PM_{10} and TSP measured at four different areas show the values below the Malaysian Air Quality Guideline (set at 25°C and 101.13 kPa) i.e. 150 and 260$\mu g/m^3$ for PM_{10} and TSP respectively, except for Kapar Repair Shop which is higher. Measurements in Connaught Bridge Repair Shop were done at various locations shows PM_{10} values in the range 24.1-108.3 $\mu g/m^3$ and TSP values in the range 48.2-216.6 $\mu g/m^3$. PM_{10} in Port Dickson Power Station and TNB Research were in the range 88.8-103.5 $\mu g/m^3$ and 41.9-69.3 $\mu g/m^3$ respectively. TSP in Port Dickson Power Station and TNB Research were 177.6-207 $\mu g/m^3$ and 56.2-112.1 $\mu g/m^3$ respectively.

Under very clean atmospheric conditions; the TSP level can be as low as 0-10 ug/m^3. In a very dirty environment, TSP concentration can be as high as1,500 ug/m^3. For Connaught Bridge Repair Shop, Port Dickson Power Station, TNB Research, and Kapar Repair Shop, they have a different environment, that is, Connaught Bridge Repair Shop is a workshop with a variety of works contributes to the emission of air particulates. Port Dickson Power Station used a gas turbine engine which cause fewer problems to the air, but suffer a serious dust problem from the construction site nearby. TNB Research situated in the pleasant area and there is no specific source of dust or air particulates. Kapar Repair Shop is facing a problem from the coal stock that they used as fuel. So, the different environmental condition gives a different level of dust or air particulates. The concentration of PM_{10} is very much related to the health risk to the workers or public in vicinity. Tiny airborne particles or aerosols that are less than 100 micrometers are collectively referred to as total suspended particulate matter (TSP). These particles constantly enter the atmosphere from many sources. Natural sources include: soil, bacteria and viruses, fungi, mold and yeast, pollen and salt particles from evaporating sea water. Human sources include: Combustion products from space heating, industrial processes, power generation and motor vehicle use. Exposure to particles with an aerodynamic diameter smaller than or equal to a nominal ten micrometers, (PM_{10} - Particulate Matter 10 microns or less) which are retained deep in the lungs, may cause health problems. The health effects of atmospheric particulate matter are related to its ability to penetrate the respiratory system. In general, respiratory defense mechanisms are able to remove 99 percent of particles larger than 10 um from the inhaled air stream. Smaller particles (> 2.5 um), called "inhalable," can cling to protective mucous and removed in the upper respiratory system. Fine particles (< 2.5 um), also called "respirable," can enter the lungs and end up in lung capillaries and air sacs (alveoli).

In the lungs, particulates slow the exchange of oxygen and carbon dioxide in the blood, causing shortness of breath. The heart may be strained because it must work harder to compensate for oxygen loss. Laboratory studies show that high concentrations of components of particulate matter cause persistent cough, phlegm, wheezing and physical discomfort. Particulate matter can also alter the immune system and affect removal of foreign material from the lung (i.e., bacteria and pollen) [8, 9, 10, 11].

Table 5: Malaysian Air Quality Guideline

Malaysian Air Quality Guideline (at 25^{0}C and 101.13 kPa)	
PM_{10}	**TSP**
150	260

Table 5 listed the Malaysian Air Quality Guideline for PM_{10} and TSP. This guideline is very useful for every organization in order to maintain the clean and healthy environment.

The profile of the air particulates can be measured continuously over a period of times. Figures 1, 2 and 3 show the measurements done in Port Dickson Power plant for 24 hours period. It shows the particulate matters are not constant over a period of times. In this case, the concentrations tend to be higher during the day and continue till midnight. Between 3.00 am and 8.00 am, the particulates concentrations are at the lower end, perhaps due to less or no human activity during this period. The particulate concentrations are depending on the wind or other influencing factors at that particular time such as temperature and humidity. Wind speed and directions will determine the amount of particulate matter at one particular point, since this particulate matters were transported by wind into various direction and distance from the source. The amounts of rain fall also contribute to the concentration of air particulates in the air, where it's going to be lower during rainy days. Malaysia is well known for its heavy rainfall. The rain can reduce the amount of air particulates in the air because most of it will be carried away by rain water.

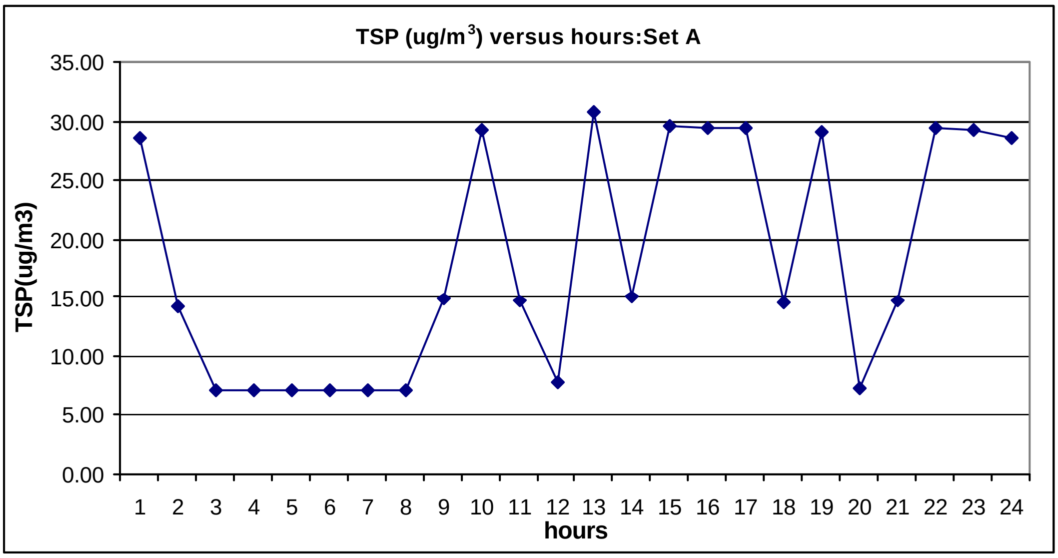

Figure 1: Profile of TSP measured at location A

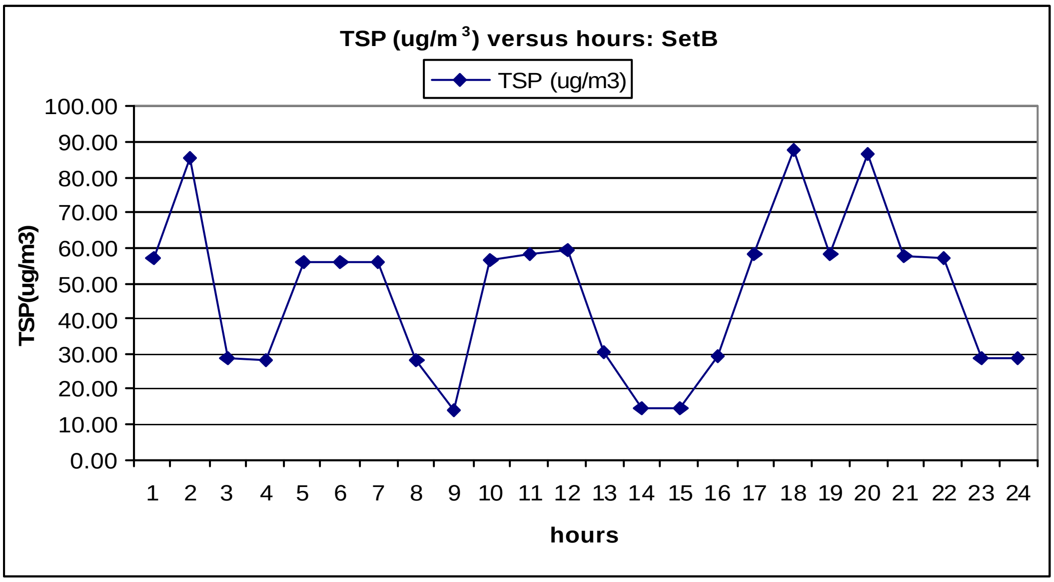

Figure 2: Profile of TSP measured in location B

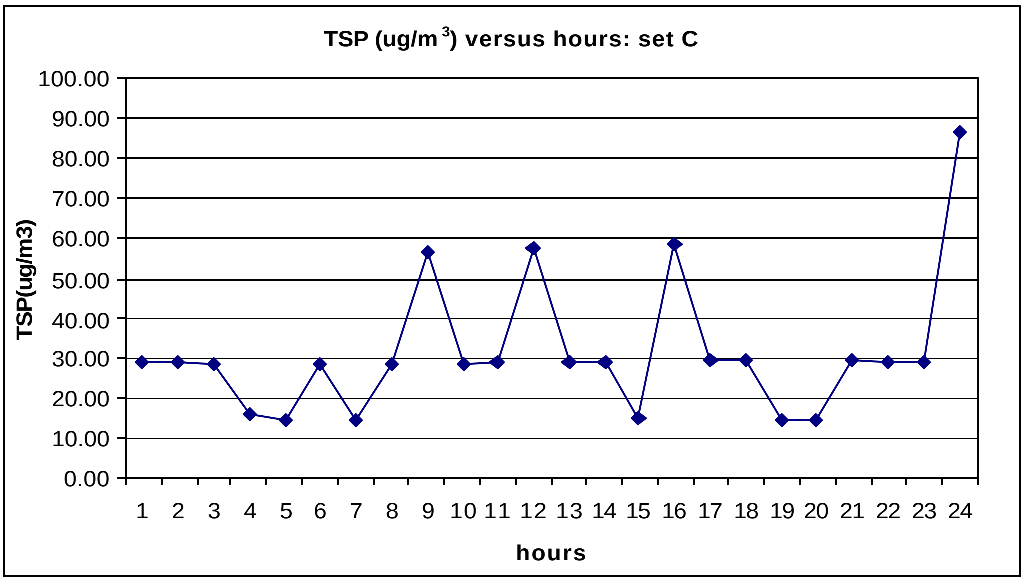

Figure 3: Profile of TSP measured in location C

Conclusion

The concentration of air particulates PM_{10} and TSP measured in different plant show different results. Air particulate matters are very much dependent of the source, the influencing factors such as wind, temperature, humidity and rain. The results are reasonable except for Kapar Repair Shop where the source of particulate is understood.

Acknowledgement

We would like to thank the staffs of Port Dickson Power Plant, Kapar and Connaught Bridge Repair Shops for allowing us to carry out this project. Also, to Water and Air Laboratory staffs, for samples analysis and Ms Hamidah Sakeh for her assistance.

References

[1] Air_quality_in_south_east_queensland
http://www.epa.qld.gov.au/environmental_management/
[2] Criteria Air Pollutant Particulate Matter (TSP and PM-10) in Minnesota control agency (1997)

http://www.pca.state.mn.us/air/emissions/pm10.html
[3] Total suspended particulates, Wisconsin Dept. of Natural Resources, retrieved at 16 March 2006 at http://www.dnr.state.wi.us/org/aw/air/health/tspart.htm
[4] Levy.J,Hammitt.K.J and Spengler.D.J(2000) Estimating the mortality impact of particulate matter: What can be leraned from Between –Study Variability, Enviromental Health Perpectives, Vol. 108, No 2
[5] Nam.C.J,Kim.TH and Chun.Y (2003) Characteristics of Airbone Particles in SEOUL during Springtime of 2003
[6] Filter paper for air sampling , retrived in 24 march 2006 at Http://www.geneq.com/catalog/en/filter_papaer.html
[7] 10 CSR 10-6.030 Sampling Methods for Air Pollution Sources (1992)
[8] Environmental Monitoring Program –Air (2002) Annual Environmental Report Federal Environmental Monitoring Hand Book, US. Department and Energy Office of environmental policy and assistant RCRA/CERCLA, 1997
[9] Thermal Power: Guideline for new plants, Pollution Prevention Abatement handbook, 1998
[10] PART 50—National Primary and secondary ambient air quality retrieved in 23 march 2006 at http://www.washingtonwatchdog.org/documents/cfr/index.html
[11] Airborne particulates retrieved in 23 march 2006 at http://www.qld.gov.au/