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The Analysis of Total Suspended Particles (TSP) emitted by the motor vehicle in An Urban Areas: Kuala Terengganu Case Study.

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Abstract

The Total Suspended Particles (TSP) concentration levels were measured at a road kurbside in selected areas in Kuala Terengganu City. The aim of this study is to develop a mathematical equation between TSP and meteorological parameters. The objective is to determine the most significant parameters influenced the TSP levels in an urban area. The sampling areas were characterized into an open and enclosed area which based on the distance to the nearest structures nearby and were representing an idling mode of the motor vehicles movements. The results indicate that the mean for TSP is significantly higher in an open spaced, which is 120 $\mu g/m^3$ compared to 89 $\mu g/m^3$ in an idling enclosed area. It were indicated in this study that high correlation between TSP levels and meteorological parameters namely humidity, temperature and wind speed were higher in an enclosed areas which is more than 0.60 compared to an opened areas which indicates approximately about 0.53. The buildings surroundings and the motor vehicles were found influenced the concentration of pollutant. The coefficient of determination value of the model developed were found more than 0.5 which indicate that the adopt method of analysis in analyzing and predicting the air pollution data were accepted.

Key words: Total Suspended Particles, Air Pollution, Motor Vehicles, and Statistic.

1.0 Introduction

Atmospheric pollutants are responsible for both acute and chronic effects on human health (WHO, 2000). Air pollution is a major environmental health problem, affecting the developed and developing countries in the world. Increasing amounts of potentially harmful gases and particles are being emitted into the atmosphere at a global scale, damaging the human health and the environment. Motor vehicle emission has been recognized as one of the major sources of air pollution, particularly in highly urbanized areas. The main traffic-related pollutants are carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons, and particulate matter and sulfur oxides (SO_2). In the air quality studies, the total aerosol suspended in air once was measured as total suspended particles (TSP). This measurement reflects the perception of smoke in the air and diminished visibility.

It has been identified that there are three major sources of air pollution in Malaysia namely mobile sources, stationary sources, and open burning sources. Based on the 1992 study by the

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Japan International Cooperation Agency, it was concluded that the air pollution problem in Kuala Lumpur is relatively serious when compared to the accepted air quality standards. The annual and daily readings for CO, Ozone and PM_{10} have exceeded the standard. Unfortunately follow-up studies in 1994 continued to shows serious problem, and motor vehicles were again found to be the main source of air pollution (Walsh *et al.*, 1997). The increasing number of people having chronic diseases can be related with the high exposure to the air pollution such as asthma, respiratory tract and others. It was reported from the study that was done by Synovate Inc. (2005) which involve 4,500 respondents from across major urban cities in China, Hong Kong, Malaysia, the Philippines and Thailand was that the air pollution is having a significant impact on their lives and that the pollution was not improving. The report indicates that the air pollution affects the people in different ways with 82 % of respondents indicating that they were experiencing irritation to their eyes, nose and throat, 57 % breathless or having more difficulties in breathing and 27 % attributes skin problems to the pollution.

1.1 Air quality in Malaysia

Malaysian ambient air quality standard identify individual pollutants and the concentrations at which they could be harmful to the public health and the environment. Table 1 lists the recommended Malaysian Air Quality Guidelines (Ambient Standards) and compares with the National Ambient Air Quality Standards currently enforced in the United States and WHO guidelines and fairly consistent with the standards of United States. In urban environments and especially in those areas where population and traffic density are relatively high which contribute about 75 % of the total CO and TSP as well as about 76 – 79 % of the oxide of sulfur and nitrogen (DOE, 1991).

Table 1 Ambient air quality standards – Malaysia, United States and WHO.

Pollutants	Average	@NAAQS Standard	*WHO Standard	#MALAYSIAN Standard
PM_{10}	1 hr 24 hr	50 µg/m³ 150 µg/m³	10 – 20.0 g/m³	50 µg/m³ 150 µg/m³
SO_2	Annual 24 hr 1 hr	0.03 ppm 0.14 ppm 0.5 ppm	0.001 – 0.01 ppm	0.025 ppm 0.04 ppm 0.13 ppm
CO	8 hr 1 hr	9 ppm 35 ppm	1.0 ppm	9.0 ppm 30 ppm
NO_X	Annual 1 hr 24 hr	0.053 ppm	0.001 – 0.01 ppm	0.05 ppm 0.17 ppm 0.04 ppm

Sources: *WHO Air Quality Guidelines (1987), #Malaysia Air Quality (1989), @EPA National Air Quality and Emissions Trends Report, United States (1995).

This hazardous substances exposure of the environment to human is expected to be significantly increased with the number of vehicles increasing from year to year. According to the Annual Report of the Road Transport Department of Malaysia, the number of registered road vehicles has increased from more than 6.8 million in 1995 to over 11.3

million in June 2001, representing a 53% increase. The composition of road vehicle fleet is 51% motorcycles, 32% cars, 7% vans and the remainders are buses, heavy goods vehicles and others. Petrol-fuel vehicles accounted about 92% of all road vehicles while the remaining 8% is diesel-operated. Table 2 shows the summary of the number of vehicles registered and the total pollutants emitted from the motor source for the year 2000 and the year 2001.

Table 2 Total vehicles registration and air emission load by gasses in Malaysia for the year 2000 and 2001.

Year	Vehicles Registration Number (millions)	Carbon Monoxide (tonne metric)	Nitrogen Oxide (tonne metric)	Hydrocarbon (tonne metric)	Sulfur Dioxide (tonne metric)	Particulate (tonne metric)	Emission from Motor Vehicles(%)
2000	10.6	2.27 mil	349,005	134,227	374,223	109,386	81 %
2001	11.3	2.26 mil	247,597	128,234	167,958	73,727	89 %

Source: Malaysia Environmental Quality Report, 2000 & 2001, Department of Environmental Malaysia.

2.0 Materials & Methods

2.1 Transportation and air pollution studies

Pollutant concentrations were found to be considerably higher at intersections and even much higher where streets are under elevated expressway. Based on studies carried out by Claggett *et al.* (1991) they have observed that pollution concentrations are higher near traffic junctions, where queuing occurs, than at the intermediate links. The results show that CO concentration may be substantially higher at signalized intersections of an arterial street than when near freeways even with two to three times higher traffic volumes. They have also shown that CO concentrations measured in the queue zone at the intersections can be attributed to the high rate of CO emissions from idling engines of vehicles stopping during red traffic signal cycle and reduced dispersion due to lack of traffic generate turbulence. This is because vehicles spend longer periods of time near junctions while queuing, decelerating or accelerating which generate more pollutants than during the steady cruise. The nature of surrounding buildings has found to be influencing the traffic pollutants (Hickman, 1976). The buildings and structures effects to the pollutant concentration were discussed by many others like Hassan *et al.,* (1998) and Hongchang Zhou *et al.,* (2001). The impact of air pollution on urban environments has become an important research issues, leading to numerous modeling studies related to the influence of buildings and other urban structures on pollutant accumulation and dissipation pattern (Sotiris *et al.,* 2003). The latest study by Noor Zaitun *et.al.,* (2002),Noor Zaitun *et.al,* (2003), Noor Zaitun et.al, (2005) gave some input on how to predicts the concentration trends of pollutants caused by complex dispersion processes nearby buildings in Malaysia.

2.2 Data Collection and Analyses

In this study, the measurements of pollutant, traffic volume and meteorological data were gathered at an arterial intersection in Terengganu City Center in a state of Terengganu, Malaysia. A sampling site criteria given by Harrison et al., (1986) was been used as a basis to determine the differences between the types of locations. A general rule adopted was that the top of obstructions such as buildings should subtend less than 30^0 angles with the horizontal at the sampling site. If the top of the building subtends more than 300 angles, the location was considered an enclosed zone while an open zone location was a location where the angle to the top of the building is less than 30^0.

The five minutes average concentration of pollutant was measured using Casella Microdust Pro. It is a real time dust monitor and was used to measure the total suspended particles (TSP) in the air at the road side. The unit measurement of TSP was in µmg/m^3. The data was measured and recorded by the five minutes interval time and the traffic volume was counted manually at 15 minutes interval. In addition, the nomad real time Portable Weather Station was used to measure the meteorological parameters namely the wind speed, humidity, air temperature, pressure and solar intensity and were measured and recorded for interval time of five minutes. The equipment was allocated approximately 5 meter from the kurbside and at 1.5 meter from the ground level height. The units of measurements for the meteorological data are wind speed (ms^{-1}), air temperature (°C), solar intensity is Wm^{-2} and humidity is in percentage (%).

Due to the mixed traffic composition in Malaysia, it is necessary to relate the capacity effect of various vehicle types to conventional passenger car and was been done using the equivalent passenger car unit (pcu). PCU values were employed as a device to convert a traffic stream composed of a mix vehicle types into an equivalent traffic stream composed of exclusively passenger cars. PCU values are employed as a device to convert a traffic stream composed of exclusively passenger cars (Arahan Teknik, 1987). While the data obtained from this study was analysed by using comprehensive statistical software known as *SPSS Base 12.0* to analyze the pollutant concentration.

3.0 Results and discussion

In general, it was found that the TSP levels were high in an enclosed area which was 120 µg/m^3 compared to 89.0 µg/m^3 in an opened areas even with large number of vehicles passed by the opened space. This can be concluded that wind flow blew in an opened areas will dispersed and effects the TSP concentration. In addition, the obstruction of the building in urban areas significantly influence TSP levels. The summary of the TSP levels and other parameter obtained from this study are shown in Table 3.

Table 3 Summary of data for enclosed and opened areas.

Parameter	Enclosed Space 1 Bank Pertanian	Opened Space 1 State library	Enclosed Space 2 Kokitab	Opened Space 2
Traffic Volume(pcu/hr)	849	481	1074	1937
TSP (µg/m^3)	97.56	92.28	120.0	89.0
Wind Speed(km/hr)	1.16	1.36	NA	NA
Temperature, ^{o}C	32.11	29.67	NA	NA
Humidity, (%)	60.94	67.84	NA	NA
Solar Intensity, Wm^{-2}	546.55	546.93	NA	NA

3.1 Relationship between motor vehicles and the TSP concentrations

The linear regression analysis has been used to analyze the relationship between two variables. The method of least square was used as a tool to estimate the relationship between the numbers of motor vehicles passing the road and the TSP concentrations. The least square estimation was used to yield reliable estimates of β_0 and β_1 and the following must be true about error (**ε**). The random disturbances are normal zero mean, homogeneous and independent. From the analyses, the relationship between TSP and PCU/min in is 0.737 in an enclosed area. It can be conclude that 73.81% of TSP in air is influenced by the number of vehicles passing the road. Figure 1 shows the scattered graph between passenger car unit and the TSP concentration in this area. In addition, the R^2 value between TSP and traffic volume (in passenger car unit, pcu/15 minutes) is 0.544 which is more than 0.5. It can be concluded that the model obtained from the analysis is acceptable. Table 4 and Table 5 summarized the relationships and the coefficient of determinations between the parameters obtained from this study.

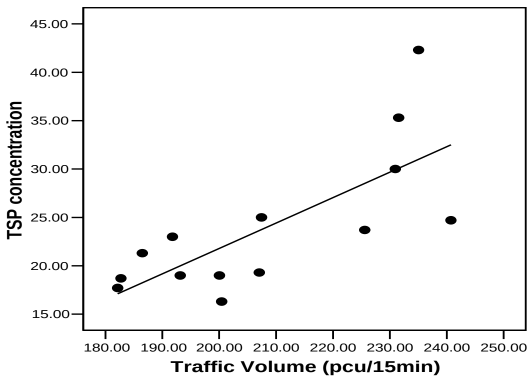

Figure 1 Relationship between TSP concentration (μg/m^3) and traffic volume (pcu/15 min) in an enclosed area

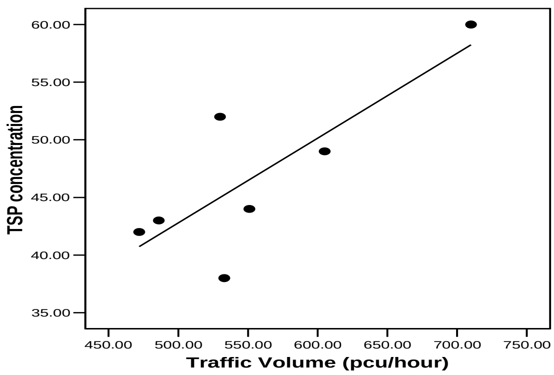

Figure 2 Relationship between TSP concentration (μg/m^3) and traffic volume (pcu/hr) in an opened area.

From the results, it can be concluded that exhaust emission from vehicles contains high TSP originated from engine dust, pollutant gases molecules or fuel combustion. Different engine capacity emits different level of pollutants (PCU conversion factor). As the vehicle hits the road, unsettled dusts and sand particles on the paved roads are suspended into air. The other factor that influence the high concentrations of TSP are the existence of diesel and petrol fuel vehicles in this areas. In addition, vehicle exhaust fumes that exist in particular form also cannot get blown away because the buildings on each side protect the street from the wind and this increases the TSP concentration.

Table 4 Regression analysis for enclosed space and meteorological parameters model results

PARAMETER	ENCLOSED SPACE		EQUATION
	R	R^2	
PCU/15min	0.74	0.54	TSP=0.26(PCU/min)-30.80+ε
Wind Speed	0.82	0.68	TSP=19.51(wind speed)-1.12+ ε
Temperature	0.76	0.58	TSP=19.51(wind speed)-1.12+ ε
Humidity	0.81	0.65	TSP= -1.43(humidity) +113.41+ ε
Solar Intensity	0.80	0.64	TSP= 0.02(solar intensity)+14.82+ ε

Table 5 Regression analysis for opened space and meteorological parameters model results

PARAMETER	OPEN SPACE		EQUATION
	R	R^2	
PCU/hour	0.80	0.65	TSP= 0.07(PCU/hour) +6.00+ ε
Wind Speed	0.80	0.64	TSP= 30.45(wind speed) - 9.45+ ε
Temperature	0.73	0.53	TSP= -6.96(temperature) +228.38+ ε
Humidity	0.74	0.54	TSP= 1.69 (humidity) -98.18+ ε
Solar Intensity	0.75	0.56	TSP= -0.07(solar intensity) +56.31+ ε

3.2 The relationship between TSP concentration and the meteorological parameters

In an enclosed area, the relationships between TSP concentration and the meteorological parameters were between 0.76 for the temperature and 0.82 for humidity. The highest correlation between wind speed and TSP is 0.82 meaning that 82 % of TSP in air influenced by wind speed. The mathematical derived between the traffic volume in PCU per fifteen minutes and the TSP concentration from the analyses is shown in Table 4. The scatter graph for passenger car unit and TSP concentration is shown in Figure 3. A correlation coefficient (R) measures the strength of a linear association between the variables. From the Table 4 and 5 the regression (R^2) between TSP and humidity is 0.648. The correlation between humidity and TSP is 0.805 meaning that 80.5% of TSP in air influenced by humidity. The R^2 value is more than 0.5. Therefore the linear equation obtained from the analysis is acceptable: From the graph, humidity is in the inverse relationship with TSP concentration value. As humidity increases, TSP concentration in air decreases. Humidity also has an inverse relationship with temperature. Humidity decreases as temperature increases.

However, the relationship between the TSP concentration and the meteorological parameters were slightly lower in an opened area which is between 0.73 and 0.80. The highest R^2 value was obtained for speed of the wind which is 0.64. The details of the model developed in this study are summarized in Table 5. Figure 4 show the scattered graph for TSP concentration and wind speed.

In this study, the high correlation coefficient between the variables was found to be more than 0.5 which represented both sites. This shows that the goodness of fit the line obtained from the analyses are accepted since the R^2 values are above 0.5. In implementing of the equation, it can be used to predict TSP concentration at the other locations which representing the same background. It can be concluded that the meteorological factor influences the TSP levels in an opened and enclosed areas.

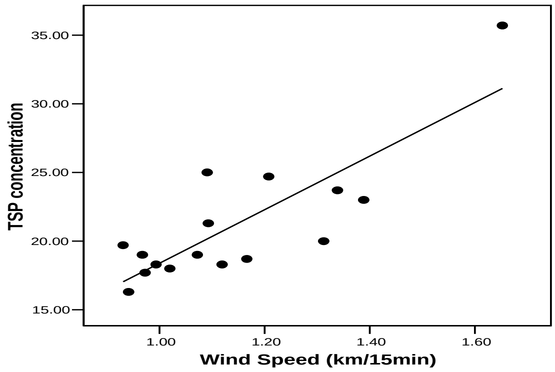

Figure 3 Relationship between TSP concentration (µg/m^3) and wind speed (km/15 min) in an enclosed area

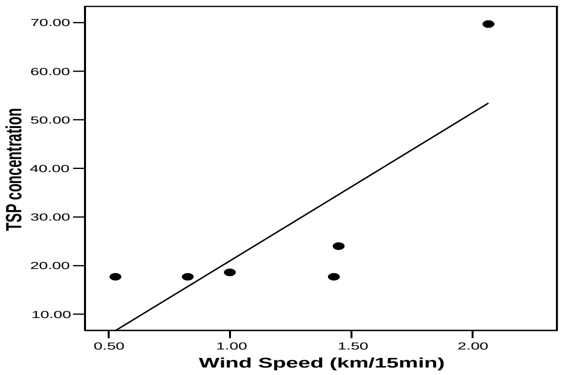

Figure 4 Relationship between TSP concentration (µg/m^3) and wind speed (km/15 min) in an opened area.

4.0 Conclusion

In summary, the TSP levels were found to be higher in an enclosed space compared to opened space. Idling mode of the motor vehicles effects the intersections with saturated traffic can have a large effects of the amount of pollutants in the urban areas. Analysis of the meteorological parameters that includes passenger car unit (PCU/min), total suspended particles (TSP), wind speed, humidity, and solar intensity for the different locations showed significant differences between characteristics at an enclosed and an open surrounding. This study significantly indicates that the traffic was the main sources of pollutant in this area. In addition, the meteorological factors were also being identified as the factors that influence the concentration of TSP. This due to air near the surface of the earth is warmer because of the absorption of the sun's energy. The warmer and lighter air from the surfaces rises and mixes with the cooler and heavier air in the upper atmosphere which results in dispersal of polluted air. Reducing humidity will increase the dispersion of TSP in air and commonly this will reduce the TSP concentration on air. Thus explains the lower TSP concentration at the sampling area when reduced humidity is recorded. The increases of solar intensity will increase the air temperature in the surrounding area. As enclosed area is blocked by buildings, the heat that increases will be trapped between buildings. The ventilation in an enclosed area is restricted and the concentration of TSP increases. Particles dispersion is reduced due to the enclosed area.

From this study we have developed a mathematical model relating total suspended particles concentration with traffic volume and meteorological factors. Another enhancement would be more elaborate the treatment of the traffic flow and the town planning design. The high correlation obtained between those parameters should admit with other variables in future such as carbon monoxide, sulfur dioxides, benzene and particulate matter. In addition, another study on characterizing the chemical compound and toxic characteristics of particles will be among the focus in the future. Although this study is a fundamental study in this area but this findings show that a bigger concern must be taken by the authority due to an exposures to this particles among the urban areas. As a developing country there are a lot of concern has to be done before any suggestion being accept by the authority to include environmental concern in their plan.

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