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Mapping the Spatial Distribution of Criteria Air Pollutants in Peninsular Malaysia Using Geographical Information System (GIS)

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1. Introduction

Air pollution is defined as the introduction by man, directly or indirectly, of substances into the air which results in harmful effects of such nature as to endanger human health, harm living resources and ecosystems, cause material damage, interfere with amenities and other legitimate uses of the environment (United Nations Environment Programme [UNEP], 1999). The air pollution sources is categorized according to form of emissions whether gaseous or particulates. Air pollution sources also can be distinguished by primary or secondary air pollutants. Primary air pollutants are in the atmosphere that exists in the same form as in source emissions, whereas, secondary air pollutants are pollutants formed in the atmosphere as a result of reactions such as hydrolysis, oxidation, and photochemical oxidation (David Liu & Lipták, 2000). World Health Organization (WHO) had been listed six "classic" air pollutants: carbon monoxide (CO), lead, nitrogen dioxide (NO_2), suspended particulate matter (SPM) sulphur dioxide (SO_2) and tropospheric ozone (O_3) (World Health Organization [WHO], 1999).

In Malaysia, the country's air qualities were monitored by Department of Environment (DOE). The five main air pollutants focus in Malaysia air quality monitoring are CO, O_3, NO_2, SO_2 and respirable SPM of less than 10 microns in size (PM_{10}).

CO is a colorless, odorless, tasteless gas. It produced by the incomplete combustion of carbon-based fuels and by some industrial and natural processes. NO_2 is colorless, slightly sweet, relatively nontoxic gas. It has a pungent, irritating odor and, because of high oxidation rate, is relatively toxic and corrosive (Godish, 2004). O_3 is formed in the air by the action of sunlight on mixtures of nitrogen oxides and VOCs. O_3 concentrations are higher in the suburbs and in rural areas downwind of large cities than in the city centre, due to ozone removal from the air by reactions with nitric oxide and other components. SO_2 is a colorless gas, which emitted from the combustion of fossil fuels and industrial refining of sulphur-containing ores (McGranahan & Murray, 2003). Respirable SPM is a suspension of solid and liquid particles in the air (Moussiopoulos, 2003). The aerosol particles with an aerodynamic diameter of less than 10 µm and 2.5 µm are referred to as PM_{10} and $PM_{2.5}$ respectively (Mkoma et al., 2010). The particles are also sites for accumulation of compounds of moderate volatility (Brimblecombe & Maynard, 2001). Many particulates in the air are metal compounds that can catalyze secondary reactions in the air or gas phase to produce aerosols as secondary products (David Liu & Lipták, 2000).

1.1 Monitoring stations in Malaysia

Department of Environment (DOE) monitors the country's ambient air quality through a network of 51 Continuous Air Quality Monitoring stations (CAQM) (Department of Environment [DOE], 2008). Location of the CAQM in Peninsular Malaysia and East Malaysia are shown in Figure 1 and Figure 2 respectively.

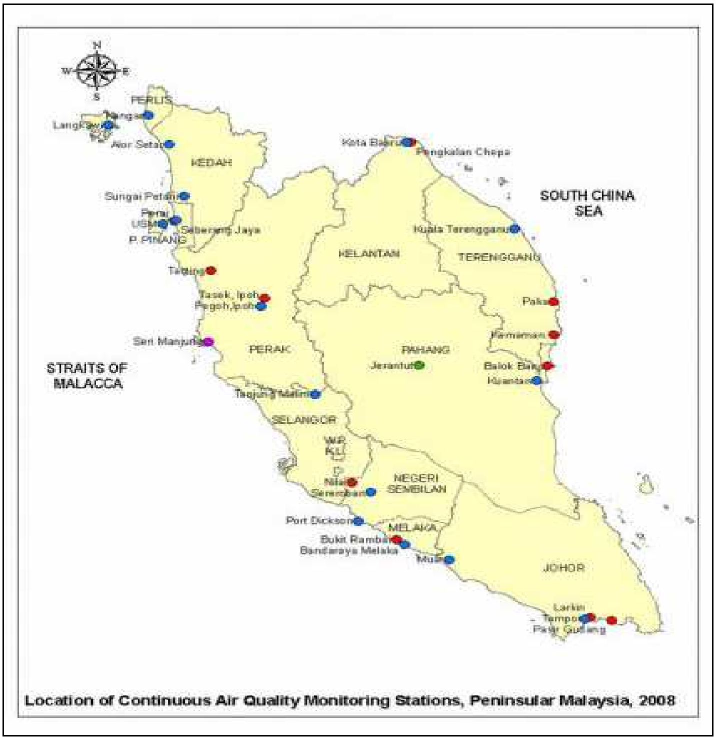


Fig. 1. Location of CAQM, Peninsular Malaysia, 2008 (Source: DOE, 2008).

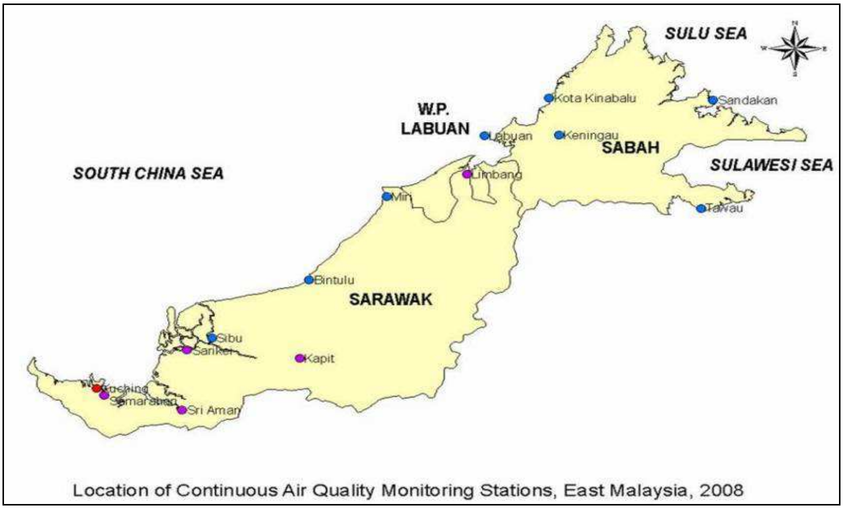


Fig. 2. Location CAQM, East Malaysia, 2008 (Source: DOE, 2008).

CAQM monitors a wide range of anthropogenic and natural emissions, there are SO_2, NO_2, O_3, CO, and PM_{10} (Parkland Airshed Management Zone [PAMZ], 2009).

CAQM (Figure 3) is designed to collect or measure data continuously during the monitoring period. CAQM typically include measurement instrumentation (for both pollutant gases and meteorological parameters); support instrumentation (support gases, calibration equipment); instrument shelters (temperature controlled enclosures); and data acquisition system (to collect and store data) (DOE, 2008).

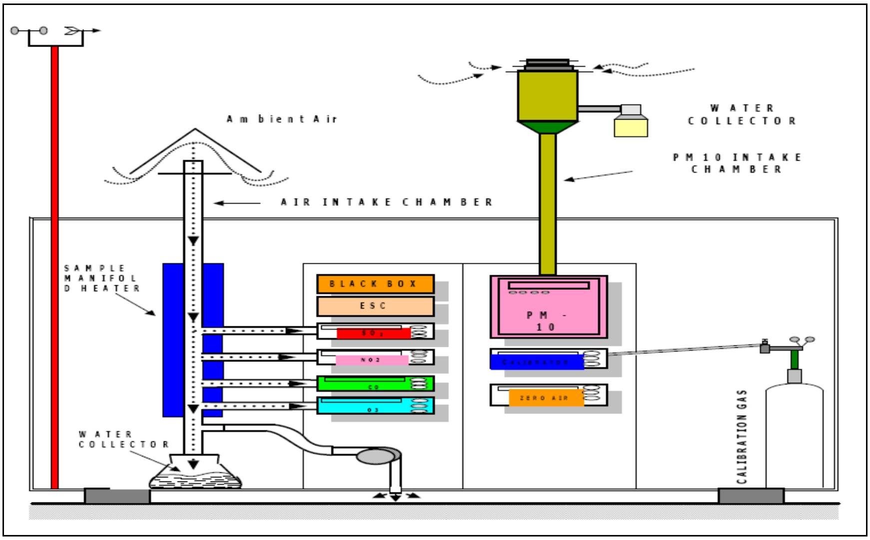


Fig. 3. Schematic Diagram of CAQM (Source: DOE, 2008).

DOE Malaysia publishes the air quality status to public using Air Pollutant Index (API) system on its website. The API system of Malaysia closely follows the Pollutant Standard Index (PSI) system of the United States.

An API system normally includes the major air pollutants which could cause potential harm to human health should they reach unsafe levels. The air pollutants included in Malaysia's API are O_3, CO, NO_2, SO_2 and PM_{10}.

The Table 1 show the category corresponds to a different level of health concern. The five levels of health concern and what they mean are (DOE, 1997):

- "Good" API is 0 - 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- "Moderate" API is 51 - 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people.
- "Unhealthy" API is 101 - 200. People with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.
- "Very Unhealthy" API is 201 - 300. This would trigger a health alert signifying that everyone may experience more serious health effects.
- "Hazardous" API greater than 300. This would trigger a health warning of emergency conditions. The entire population is more likely to be affected.

API	Descriptor
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very unhealthy
>300	Hazardous

(Source: DOE, 1997)

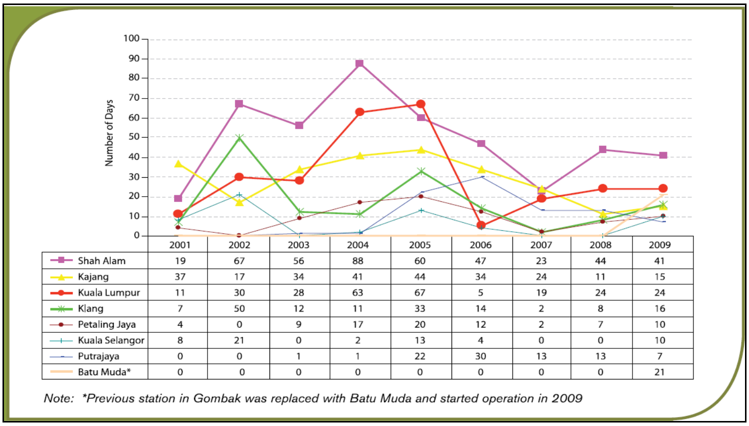
Table 1. General human health effect and cautionary statements within each of the API categories.

1.2 Trend/status pollutions and air pollutants sources in Malaysia

An annual Environmental Quality Report (EQR) had been published in compliance with the Section 3(1)(i) of the Environmental Quality Act 1974. The EQR reported that air quality, noise monitoring, river water quality, groundwater quality, marine and island marine water quality, and pollution sources inventor in Malaysia.

In Malaysia EQR 2009, the air quality status reported in 5 regions of Malaysia. There are Selangor, northern region of west coast of Peninsular Malaysia (Perlis, Kedah, Pulau Pinang and Perak), southern region of west coast of Peninsular Malaysia (Negeri Sembilan, Melaka and Johor), east coast of Peninsular Malaysia (Pahang, Terengganu and Kelantan), as well as Sabah, Labuan and Sarawak. Meanwhile, the overall air quality for Malaysia in 2009 was between good to moderate levels most of the time. However, there was a slight decrease in the number of good air quality days recorded in 2009 (55.6 percent of the time) compared to that in 2008 (59 percent of the time) while remaining 43 percent at moderate level and only 1.4 percent at unhealthy level (DOE, 2009b).

The highest number of unhealthy air quality status days was recorded in Shah Alam (41 days) for the state of Selangor (Figure 4). Figure 4 also showed that, from year 2001 until 2009, Shah Alam has the highest number of unhealthy air quality than other in the states of Selangor. The air quality of the northern and southern region of west coast of Peninsular Malaysia was between good to moderate most of the time. Then, east coast of Peninsular Malaysia the air quality remained good most of the time and occasionally moderate. Last, Sabah, Labuan and Sarawak were generally good and moderate.

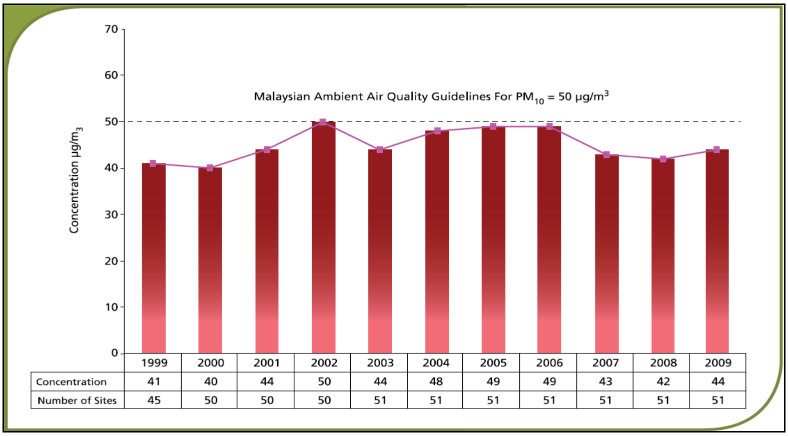


	2001	2002	2003	2004	2005	2006	2007	2008	2009
Shah Alam	19	67	56	88	60	47	23	44	41
Kajang	37	17	34	41	44	34	24	11	15
Kuala Lumpur	11	30	28	63	67	5	19	24	24
Klang	7	50	12	11	33	14	2	8	16
Petaling Jaya	4	0	9	17	20	12	2	7	10
Kuala Selangor	8	21	0	2	13	4	0	0	10
Putrajaya	0	0	1	1	22	30	13	13	7
Batu Muda*	0	0	0	0	0	0	0	0	21

*Note: *Previous station in Gombak was replaced with Batu Muda and started operation in 2009*

Fig. 4. Malaysia: Number of Unhealthy Days, Klang Valley, 2001-2009 (Source: DOE, 2009b).

The air quality trend of five air pollutants for the period of 1998 to 2009 was showed in the EQR 2009. In 2009 the annual average value of PM_{10} (Figure 5) was 44 µg/m^3 and no significant change compared to the annual average of PM_{10} (42 µg/m^3) in 2008. The higher level of PM_{10} recorded in several areas in Selangor and Sarawak from June to August 2009

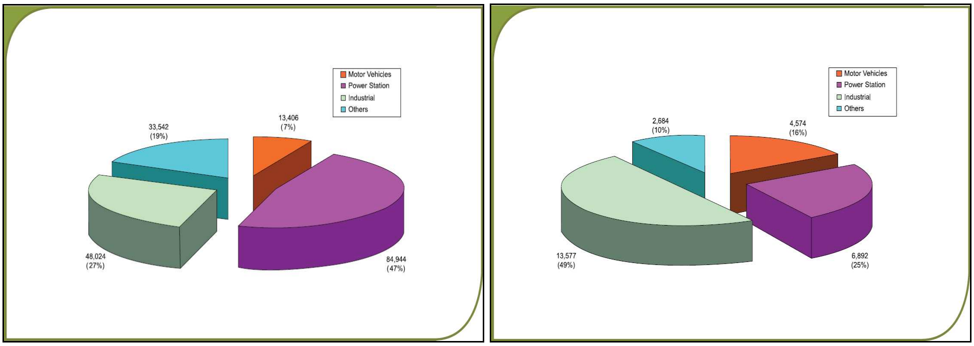


	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Concentration	41	40	44	50	44	48	49	49	43	42	44
Number of Sites	45	50	50	50	51	51	51	51	51	51	51

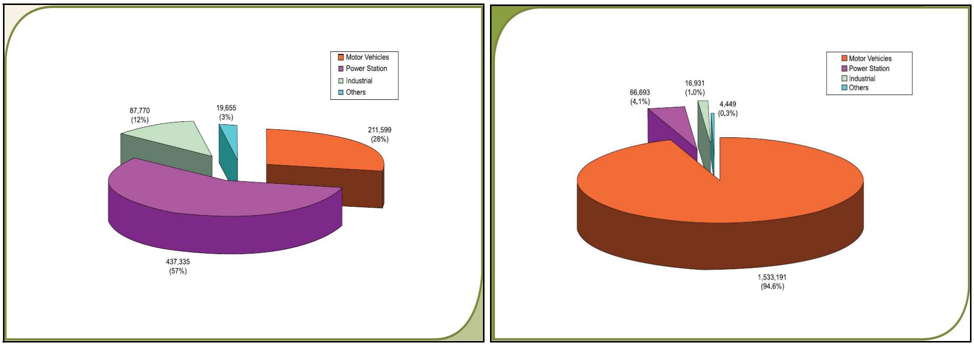
Fig. 5. Malaysia: Annual Average Concentration of PM_{10}, 1999-2009 (Source: DOE, 2009b).

was caused by the incidences of local peat land fires and trans-boundary haze (DOE, 2009b). However, the trend of the annual average levels of PM_{10} concentration in the ambient air from 1999 to 2009 complied with the Malaysian Ambient Air Quality Guidelines (PM_{10} concentration not exceed 50 µg/m^3).

In EQR 2009, it is estimated that, the combined air pollutant emission load was 1,621,264 metric tonnes of CO; 756,359 metric tonnes of NO_2; 171,916 metric tonnes of SO_2 and 27,727 metric tonnes of PM_{10} (DOE, 2009b). There was an increase in emission load for CO, NO_2 and SO_2 compared to 2008. Figure 6 (a-d) showed the emission by source for SO_2, PM_{10}, NO_2, and CO respectively. The results reveal that, power stations contributed the highest SO_2 and NO_2 emission load, 47% and 57% respectively. On the other hand, PM_{10} and CO the highest contributor were industries (49%) and motor vehicles (95%) respectively.



(a) SO_2 (b) PM_{10}



(c) NO_2 (d) CO

Fig. 6. (a-d): Malaysia: Emission by Sources (Metric Tonnes), 2009 (Source: DOE, 2009b).

2. Spatial air pollutants mapping in Malaysia

Presenting of the air pollutant concentration or API to public always is a challenge for the DOE. Air pollutants data from the monitoring station present in numerical or literal form are wearisome and cannot well present a large surrounding area. Meanwhile, actual situation of air pollution cannot be figured out to public. Moreover, the air pollutants data present in the numerical form have lack of geographical information. Beside, the way to get more actual pollution status in a huge area, have more monitoring stations is a high cost of the solvent method. Increase the monitoring station will increase the persistence of the pollution information. However, building new monitoring station is very costly. According to Alam Sekitar Malaysia Sdn. Bhd. (ASMA), an air monitoring station is cost about one million and the station only can present the area with the radius of 15 km. In other word, bigger areas for a States require more monitoring station and the higher cost of the air quality monitoring in the States.

A picture can describe thousand words, air pollutants statuses describe in an image (spatial map) can be more easily been visualized. In this century, presenting the data in a compact and full of information ways are preferred. There are many researcher nowadays attempt to study the dispersion of air pollutants with an image. In this study, a GIS-based approach of spatio-temporal analysis is attempted to use for presenting the air pollutions situation in an area.

Geographic information system (GIS) is an integrated assembly of computer hardware, software, geographic data and personnel designed to efficiently acquire, store, manipulate, retrieve, analyze, display and report all forms of geographically referenced information geared towards a particular set of purposes (Burrough, 1986; Kapetsky & Travaglia, 1995, as cited in Nath et al., 2000). The power of a GIS within the framework of spatio-temporal analysis depends on its ability to manage a wide range of data formats, which are represented by digital map layers extended by attributes with various observations, measurements and preprocessed data (Matějíček et al., 2006). The statistical data of the GIS can include area, perimeter and other quantitative estimates, including reports of variance and comparison among images (Nath et al., 2000). GIS is useful to produce the interpolated maps for visualization, and for raster GIS maps algebraic functions can calculate and visualize the spatial differences between the maps (Zhang & McGrath, 2003).

Nowadays, the applications of the GIS become wider. The increased use of GIS creates an apparently insatiable demand for new, high resolution visual information and spatial databases (Pundt & Brinkkötter-Runde, 2000). GIS able to do spatio-temporal analysis due to its ability to manage a wide range of data formats, which are represented by digital map layers extended by attributes with various observations, measurements and preprocessed data (Matějíček et al., 2006).

Concentration of pollutant present in spatio-temporal GIS-based image allow the reader more understand the real pollution level of the area. A GIS-based image with the coordination, geographical information, and the concentration of the air pollution can figure out or visualized the pollutant level of the study area. A GIS-based image of the spatio-temporal analysis only requires few set of data from different monitoring stations. Dispersion of the air pollutants can be produced by the spatio-temporal analysis with few point of the air monitoring data. Pollution level of Malaysia can be present with lesser monitoring station build.

Various technique of interpolating that GIS allow user to interpolate the variation of air pollutants. Inverse Distance Weighted (IDW), example, estimate of unknown value via a known value with the decrease of value through the increase of the distance as a simple interpolation method for air pollutants.

2.1 Inverse distance weighted of the PM_{10} spatial mapping federal territory Kuala Lumpur

Federal Territory Kuala Lumpur has the total areas of 243 km^2 with the population of 1,655,100 people in 2009. In year 2009, Kuala Lumpur has the highest population density in Malaysia with 6,811 people per km^2 (Department of Statistics, 2009). Federal Territory Kuala Lumpur has a rapid transformation and its wider urban region during the last decade of the twentieth century demands greater critical scrutiny than it has so far attracted (Bunnell et al., 2002). Kuala Lumpur is the social and economic driving force of a nation eager to better itself, a fact reflected in the growing number of designer bars and restaurants in the city, and in the booming manufacturing industries surrounding it (Ledesma et al., 2006). Figure 7 shows the average temperature and the rainfall in area of Kuala Lumpur, temperatures have not much different and humidity is high all year around.

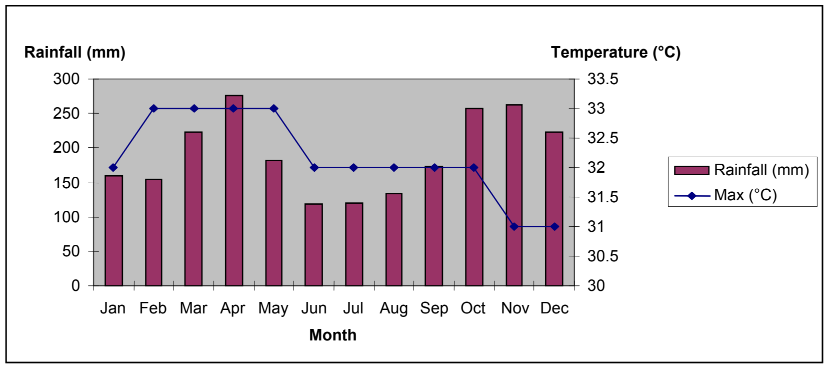


Fig. 7. Graph average daily temperature and rainfall (Source: Ledesma et al., 2006).

Air quality of a small area with a high population is the most concern issue for the government. It cannot be ignoring to study the dispersion of the pollutants. In year 1997, Kuala Lumpur and surrounding areas had been shrouded by haze with a pall of noxious fumes, smelling of ash and coal, caused by the fires in the forests to clear land during dry weather at neighbor country Indonesia's Sumatra Island (msnbc.com, 2010). In year 2005, the highest number, 67 days, of unhealthy day were recorded in Kuala Lumpur (DOE, 2006).

In section 2.1 and 2.2, IDW is the method used to interpolate the dispersion of PM_{10} concentrations in Kuala Lumpur. Changing of the study of pollutant with the air monitoring station had to change to more presentable of dispersion image form. The dispersion of the PM_{10} concentration in Kuala Lumpur using the interpolation of IDW is the first attempted to have spatial air pollutants mapping in Malaysia. Some more, API in Malaysia always show by the concentration of PM_{10} (DOE, 2009a), which mean that PM_{10} is the parameter most contribute to the air pollution in Malaysia. So that, PM_{10} was chose as study air pollutant. PM_{10} concentration data which collected from DOE are the main data were used.

There are three air monitoring stations located at the Federal Territory Kuala Lumpur. CAQM which build at Kuala Lumpur are station CA0012, station CA0016 and station CA0054 (Figure 8). Station CA0012 operated since December 1996 and ceased operation on February 2004. Whereas, Station CA0016 and CA0054 operated since December 1996 and February 2004 respectively until today both still well monitoring the air quality in Federal Territory Kuala Lumpur. However, to make the interpolation more persistent, all the PM_{10} data which the CAQM located in States of Selangor were obtained to do the interpolation of the dispersion in Kuala Lumpur. Figure 9 show the CAQM station location on Selangor map.

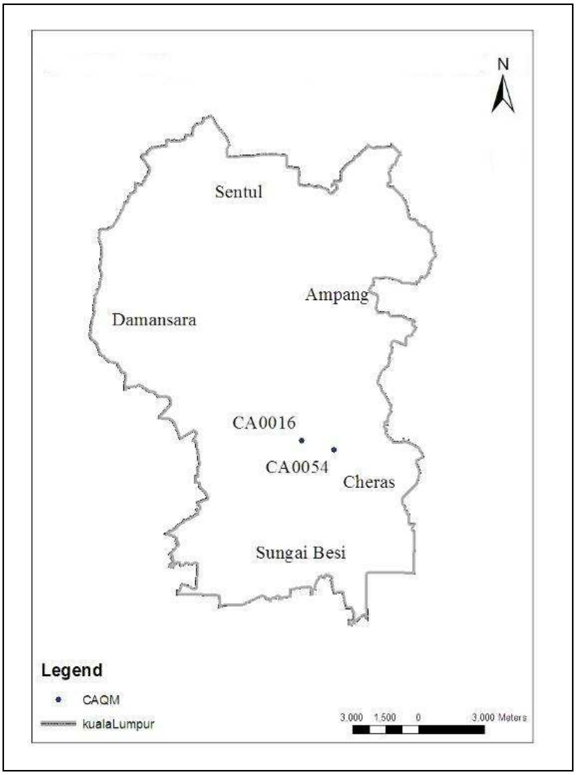


Fig. 8. Kuala Lumpur map with the located CAQM.

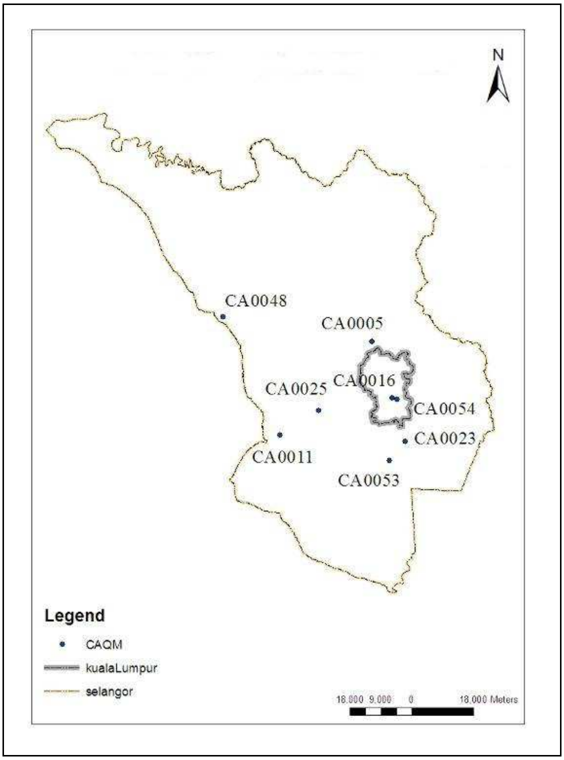


Fig. 9. Selangor map with the located CAQM.

Table 2 showed geographical information for the CAQM stations in Selangor, latitude and longitude had been converted to Rectified Skewered Orthomocphic (RSO) map projection, X-Y coordinate. RSO is a local map projection commonly used in Malaysia.

Station Code	Latitude	Longtide	x (meters)	y (meters)	Jan-04 ($\mu g/m^3$)	Feb-04 ($\mu g/m^3$)
CA0005	3°15.702'N	101°39.103'E	406223.4	360936.1	53	62
CA0011	3°00.620'N	101°24.484'E	379076.9	333208.9	65	73
CA0016	3°06.612'N	101°42.274'E	412048.4	344183.5	47	64
CA0023	2°59.645'N	101°44.417'E	416001.4	331336.1	33	48
CA0025	3°04.636'N	101°30.673'E	390551.5	340581.4	54	61
CA0048	3°19.592'N	101°15.532'E	362596.0	368240.6	57	68
CA0053	2°56'37.81N	101°41'54.25E	411326.1	325756.9	33	45
CA0054	3°06.376'N	101°43.072'E	413529.3	343750.0	44	77

Table 2. Geographical information for the CAQM stations in Selangor.

IDW interpolations for the dispersion PM_{10} concentration in Kuala Lumpur was computed by the GIS software validate with the in-situ monitoring (section 2.2.1). Then, the result will be further discussed in section 2.2. GIS software integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed.

2.2 Decision making mapping

IDW method interpolates the pollutants concentration to a spatial air pollutants mapping. Spatial air pollutants mapping clearly show the dispersion of pollutant in a study area and leave a visual tool to the decision maker or public. Referring to the dispersion of PM_{10} concentrations in Kuala Lumpur, it is more easily been visualized the air pollution status in Kuala Lumpur.

Figure 10 show the IDW interpolation of the dispersion of PM_{10} concentration in Federal Territory Kuala Lumpur March 2004. Two points shown in the map are the located CAQM stations in Kuala Lumpur. Interpolation of the dispersion PM_{10} concentration show the PM_{10} concentrations decreasing when the distance from the CAQM station increasing. The nearest areas, Cheras, shows highest interpolate PM_{10} concentration which in the range 70 – 73 μg/m^3. The interpolation show areas of Cheras having a highest value this is due to the high

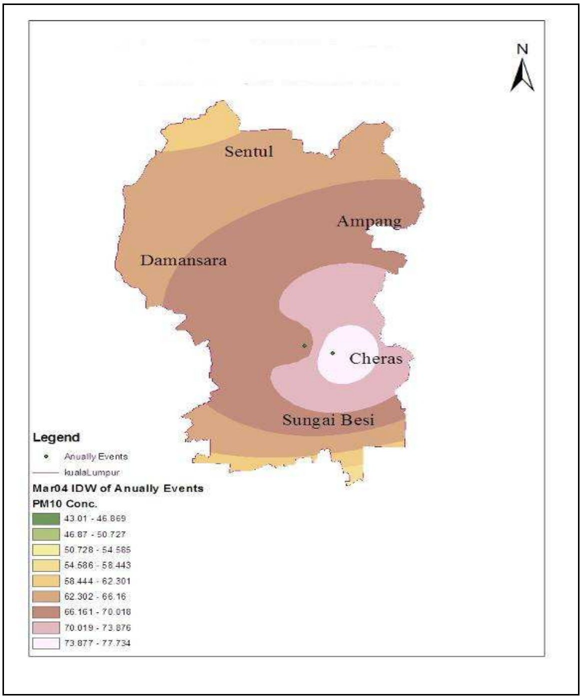


Fig. 10. Dispersion of PM_{10} Concentration at Kuala Lumpur March 2004.

PM_{10} concentration at the CA0054 obtained is high and the Cheras is the nearest to the CA0054. Then, areas of Ampang and Sungai Besi have the estimated PM_{10} concentrations about 66 – 70 $\mu g/m^3$ as well as areas of Damansara and Sentul having 62 – 66 $\mu g/m^3$ of estimation PM_{10} concentrations. The areas of Sungai Besi, Ampang, Damansara and Sentul respectively far from the CAQM areas, so that, the interpolation PM_{10} concentration decreasing across the areas.

One of the great powers of the GIS is the analysis of the values for every raster. Users can analysis the value of mean, maximum or minimum for a set of spatial air pollutants mapping. Figure 11 show the mean for the estimation dispersion of PM_{10} concentration from year 2004 until 2008. Averages of the dispersion of PM_{10} concentrations from year 2004 until 2008 are in the range of 44 – 54 $\mu g/m^3$. Areas of Cheras and Sungai Besi show the PM_{10} concentration between 52 – 54 $\mu g/m^3$. There are two factors effected the high average of the interpolation PM_{10} concentration at the middle areas of Kuala Lumpur. First, the values use for the interpolation, CAQM data, located at the middle areas of Kuala Lumpur. Second, the centering of human daily activities at the middle of Kuala Lumpur also effected the highest concentration of PM_{10} at the middle areas of Kuala Lumpur. Next, areas of Damansara and Ampang have about 49 – 52 $\mu g/m^3$ estimation of PM_{10} concentrations. As well as areas of Sentul show 47 – 49 $\mu g/m^3$ of PM_{10} concentrations. Areas far apart from the CAQM station, CA0016 and CA0054, have lower average PM_{10} concentration.

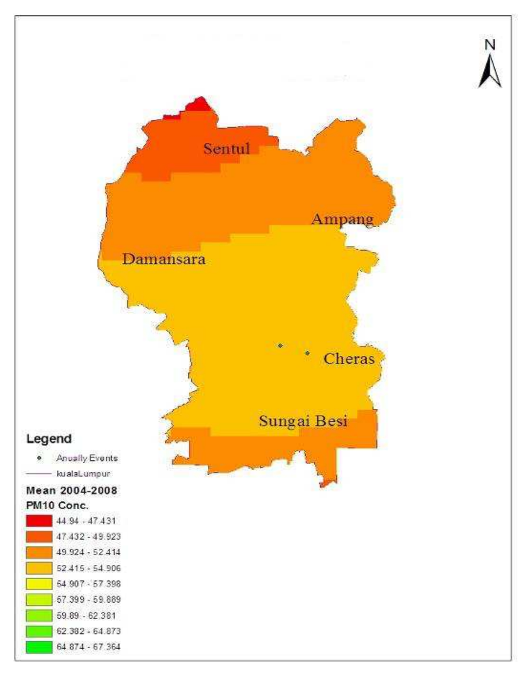


Fig. 11. Mean PM_{10} Concentration at Kuala Lumpur from 2004-2008.

Figure 12 shows the maximum for the estimation dispersion of PM_{10} concentration from year 2004 until 2008. Maximum of the dispersion of PM_{10} concentrations from year 2004 until 2008, at the middle areas of Federal Territory Kuala Lumpur, is in the range of 112 – 118 µg/m^3. The highest maximum values show are nearest to the CA0016 station, which mean that the maximum PM_{10} concentrations are obtained from the CA0016 station. The maximum values of 118 µg/m^3 have the API of 84 and this shows "Moderate" in the API status. Areas of Cheras, Sungai Besi, Damansara and Ampang show the PM_{10} concentration between 107 – 112 µg/m^3. Next, areas of Sentul show about 102 – 107 µg/m^3 of PM_{10} concentrations. All the areas in Kuala Lumpur show "Moderate" API status for the maximum PM_{10} concentration.

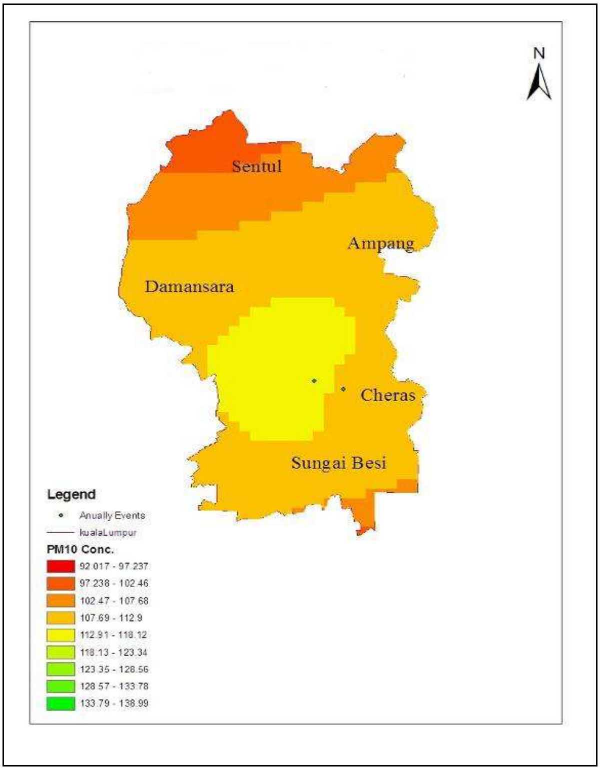


Fig. 12. Maximum PM_{10} Concentration at Kuala Lumpur from 2004-2008.

The weather in Malaysia is characterized by two monsoon regimes, namely, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March (Weather Phenomena, 2009). The dispersion of PM_{10} concentration in Federal Territory Kuala Lumpur during Southwest Monsoon and Northeast Monsoon can be easily showed by the aid of analysis tool of GIS. The haze which shrouded the Kuala Lumpur and surrounding areas in year 1997 is one of the effects of the Southwest Monsoon. The wind blowing from the Southwest bring along the air pollutant from the neighbor Indonesia's Sumatra Island. Addition, during Southwest monsoon, Peninsular Malaysia will have less rain and dry. Otherwise, during Northeast monsoon, Peninsular Malaysia will have heavy rain and flooding (Ecographica, 2010).

The mean of the PM_{10} concentration dispersion in Kuala Lumpur during Northeast Monsoon year 2004 until 2008 is show in Figure 13 Averages of the dispersion of PM_{10} concentrations during Northeast Monsoon from year 2004 until 2008 are in the range of 39 – 50 µg/m^3. The higher average of PM_{10} concentration is about 47 – 50 µg/m^3, it shown in the middle areas of Kuala Lumpur. The highest mean PM_{10} concentrations shows are nearest to the station CA0016. Areas of Cheras, Sungai Besi, Damansara and Ampang show the PM_{10} concentration between 45 – 47 µg/m^3. Next, areas of Sentul show about 42 – 45 µg/m^3 of PM_{10} concentrations. The dispersion PM_{10} concentration of mean during Northeast monsoon is similar with the dispersion of maximum PM_{10} concentration along the year 2004 till 2008. Both image shown the highest value of PM_{10} concentrations are nearest to the CAQM station, CA0016.

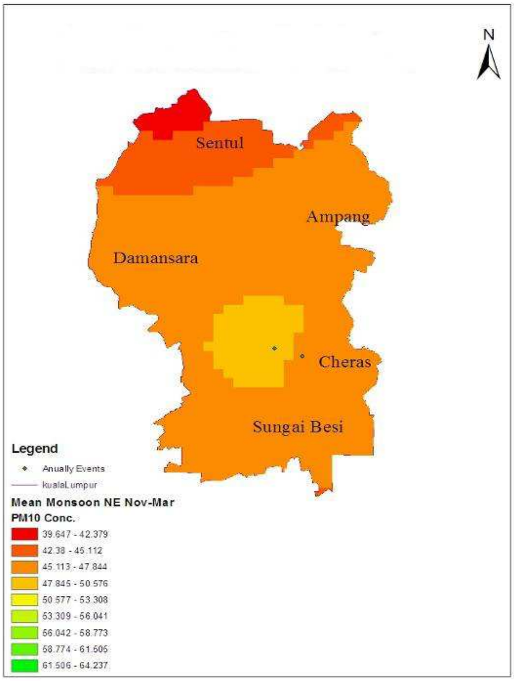


Fig. 13. Mean PM_{10} Concentration at Kuala Lumpur during Northeast Monsoon Nov-Mar 2004-2008.

Figure 14 shows the maximum for the dispersion of PM_{10} concentration during Northeast Monsoon from year 2004 until 2008. Maximum of the dispersion of PM_{10} concentrations during Northeast Monsoon from year 2004 until 2008, at the areas of Cheras and Damansara, is in the range of 54 – 58 µg/m^3. Areas of Sungai Besi and Ampang show the

PM_{10} concentration between 50 – 54 µg/m³. Next, areas of Sentul show about 47 – 50 µg/m³ of PM_{10} concentrations during the Northeast Monsoon.

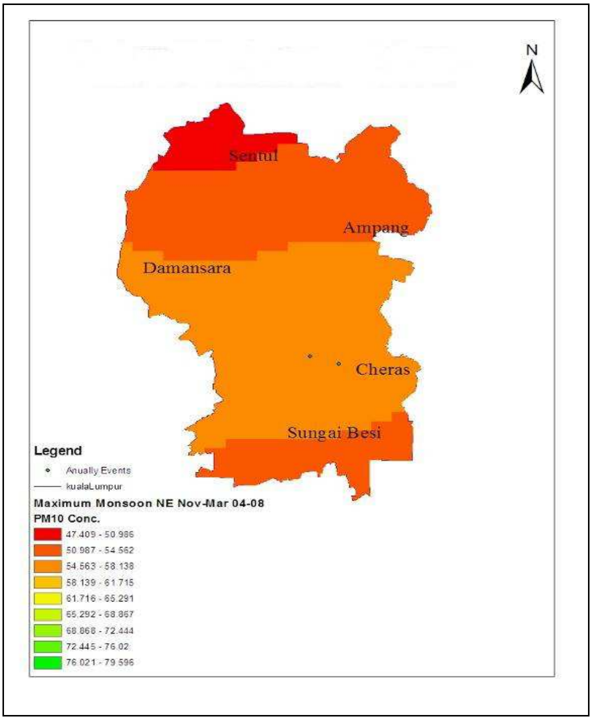


Fig. 14. Maximum PM_{10} Concentration at Kuala Lumpur during Northeast Monsoon Nov-Mar 2004-2008.

The dispersion PM_{10} concentration of mean during Northeast monsoon is similar with the dispersion of mean PM_{10} concentration along the year 2004 till 2008. During the wet season or Northeast monsoon, the maximum of PM_{10} concentration can be seen are the averaging of the PM_{10} concentration. Meanwhile, the mean of the PM_{10} concentration dispersion in Kuala Lumpur during Southwest Monsoon year 2004 until 2008 is shows in Figure 15. Averages of the dispersion of PM_{10} concentrations during Southwest Monsoon from year 2004 until 2008 are in the range of 52 – 60 µg/m³. Areas of Cheras, Sungai Besi, and Damansara show the highest PM_{10} concentration between 57 – 60 µg/m³. Next, areas of Ampang show about 55 – 57 µg/m³ of PM_{10} concentrations. As well as areas of Sentul, the PM_{10} concentrations are in the range of 52 – 55 µg/m³. The averaging of the PM_{10} concentration during Southwest monsoon or dry season is higher than the overall averaging PM_{10} concentration from year 2004 until 2008. This shows that Kuala Lumpur had a higher pollution during the dry season.

Figure 16 shows the maximum for the dispersion of PM_{10} concentration during Southwest Monsoon from year 2004 until 2008. Maximum of the dispersion of PM_{10} concentrations during Southwest Monsoon from year 2004 until 2008, at the middle areas of Federal

Territory Kuala Lumpur, is in the range of 72 – 75 µg/m³. The highest maximum PM_{10} concentrations shows are around the areas of station CA0016. Areas of Cheras, Damansara, Sungai Besi and Ampang show the PM_{10} concentration between 69 – 72 µg/m³. Next, areas of Sentul show about 63 – 66 µg/m³ of PM_{10} concentrations during the Southwest Monsoon.

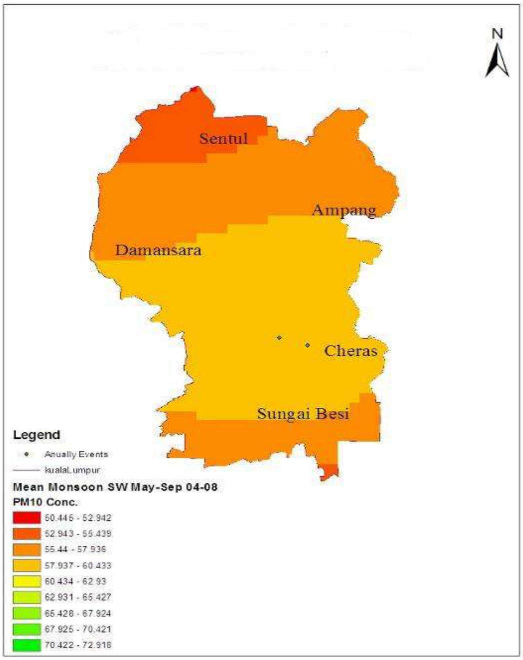


Fig. 15. Mean PM_{10} Concentration at Kuala Lumpur during Southwest Monsoon May-Sep 2004-2008.

The dispersion of PM_{10} concentration during Southwest monsoon or dry season is show similarity with the overall maximum PM_{10} concentration from year 2004 until 2008. During dry season or Southwest monsoon, the average of the PM_{10} concentration show higher value than wet season or Northeast monsoon. As well as the maximum PM_{10} concentration during Southwest monsoon also show higher than during Northeast monsoon. From Figure 15 and Figure 16, the highest PM_{10} concentration show during Southwest Monsoon. The maximum concentration of PM_{10} during Southwest Monsoon is 75 µg/m³, whereas, during Northeast Monsoon the PM_{10} concentration is 58 µg/m³. The overall maximum PM_{10} concentrations from year 2004 until 2008, it can be said similar with the mean PM_{10} concentration during Northeast monsoon and maximum PM_{10} concentration during Southwest monsoon. In other word, the overall maximum PM_{10} concentrations from year 2004 till 2008 most of it are contribute by the maximum PM_{10} concentrations during the dry season, Southwest monsoon. However, the maximum PM_{10} concentration shown in the Figure 12, Maximum PM_{10} concentration from year 2004 till 2008 is 118 µg/m³. This value is not found in the PM_{10} concentration during monsoon, it can be said that it is in intermediate of the monsoon.

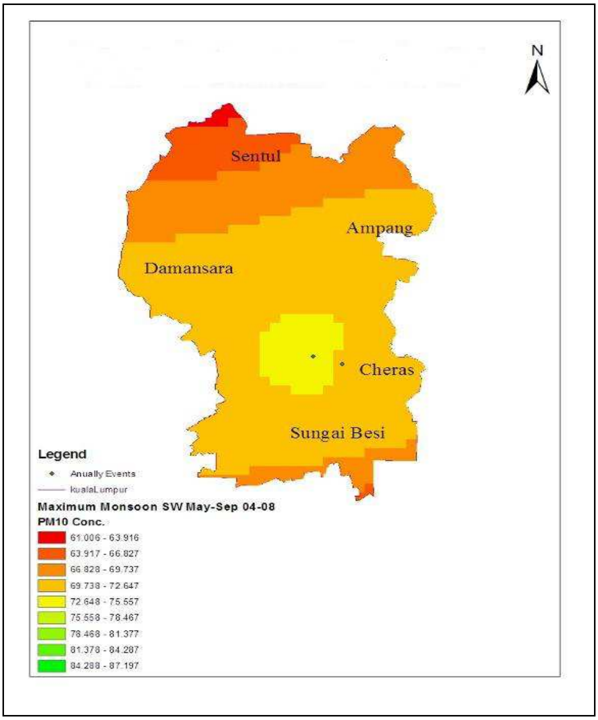


Fig. 16. Maximum PM_{10} Concentration at Kuala Lumpur during Southwest Monsoon May-Sep 2004-2008.

2.2.1 Validation of IDW interpolation

IDW interpolations for the dispersion PM_{10} concentration in Kuala Lumpur have to validate with the in-situ monitoring. Due to the differences device are using to detect the PM_{10} concentration, one relationship have to make between the data of both devices. The DOE PM_{10} concentration data is the main reference in this study. The compatible in-situ PM_{10} concentrations, after that, are used to validate the interpolation of the dispersion.

Equation 1, the regression between CAQM data and Casella Microdust Pro (PM_{10} detection device) data (Figure 17), had been formed. Equation 1 showed the linear relationship between CAQM data and Casella Microdust Pro data with the correlation coefficient of 0.148, weak relationship:

$$y = 46.173 + 0.098x \tag{1}$$

where, y is CAQM PM_{10} concentrations and x is Casella Microdust Pro PM_{10} concentrations respectively. However, equation 1 makes the Casella Micodust Pro data more compatible to the CAQM data.

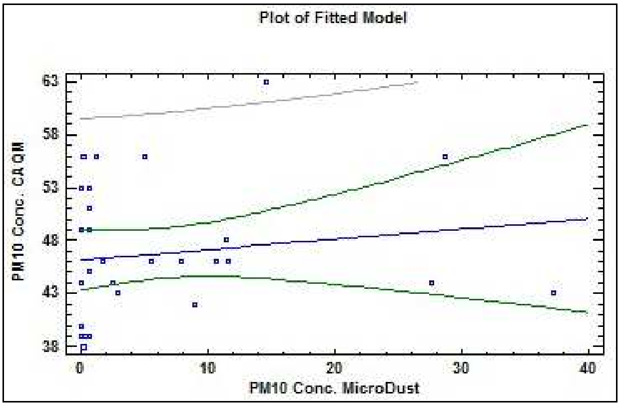


Fig. 17. Regression between CAQM data and Casella Mircodust Pro data.

Figure 18 showed the dispersion of PM_{10} concentration in Kuala Lumpur at 3pm 1/12/2009 with the selected in-situ monitoring point. The interpolated PM_{10} concentration for the selection monitoring point, Sekolah Jenis Kebangsaan (C) Chi Man, is extracted from Figure 18. The interpolated PM_{10} concentration the selected point is 30.178 μg/m³. Then, the interpolated PM_{10} concentration, data on map, compare with the in-situ monitoring PM_{10} concentration.

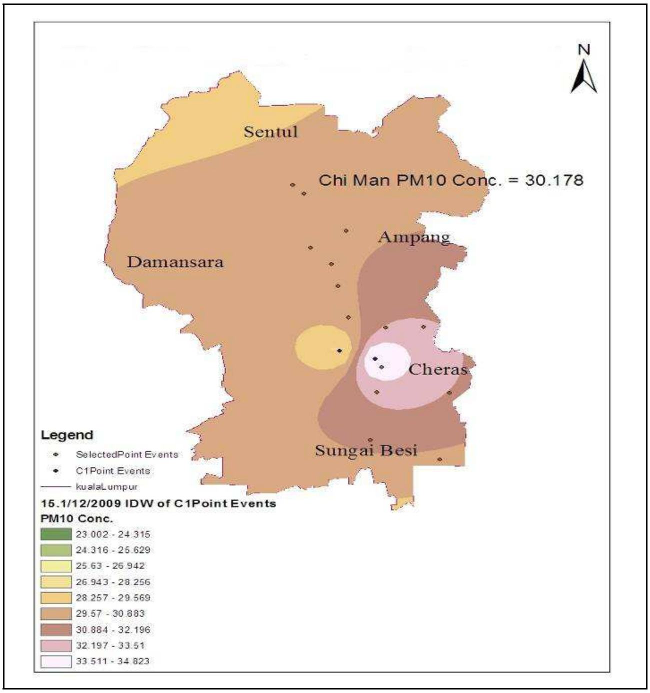


Fig. 18. Dispersion of PM_{10} concentration in Kuala Lumpur at 3pm 1/12/2009.

Equation 2, the regression between interpolated and in-situ monitoring PM_{10} concentrations, formed (Figure 19). The relationship between interpolated and in-situ monitoring PM_{10} concentrations is double reciprocal with the correlation coefficient 0.289:

$$\frac{1}{y} = 0.020 + \frac{0.042}{x} \tag{2}$$

where, y is the in-situ monitoring PM_{10} concentrations or the actual PM_{10} concentration; then, x is the interpolated or Spatio-temporal PM_{10} concentrations.

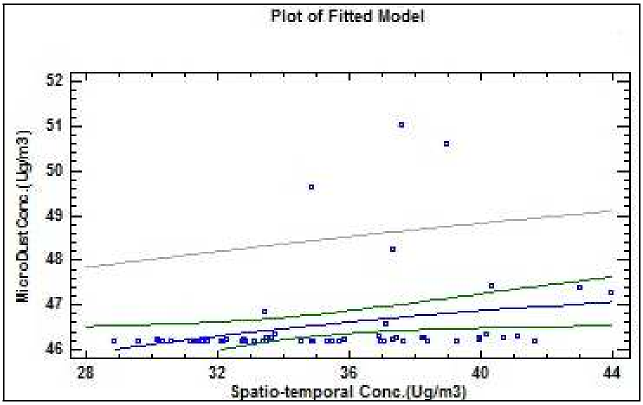


Fig. 19. Regression between interpolated and in-situ monitoring PM_{10} concentrations.

A model is considered validate if the calculated and measured values do not differ by more than approximately a factor of 2 (Pratt et al., 2004; Weber, 1982). Table 3 show a part of the interpolated (Spatio-temporal) and in-situ monitoring (Microdust) PM_{10} concentrations and have not differ by more than a factor of 2, thus, the IDW interpolation method can be used to describe the PM_{10} dispersion in Kuala Lumpur.

MicroDustConc.(µg/m^3)	Spatio-temporal Conc.(µg/m^3)
46.206	32.190
46.176	30.303
46.179	28.833
46.229	30.178
46.304	36.872
46.272	38.280
46.584	37.103
46.205	34.538
46.179	33.101
46.182	30.574

Table 3. A part of Microdust and Spatio-temporal PM_{10} concentration.

3. Conclusion

Malaysia air quality monitoring generally are focused on five air pollutants which are CO, O_3, NO_2, SO_2 and PM_{10}. Ambient air quality monitoring in Malaysia was installed, operated and maintained by ASMA under concession by the DOE through a network of 51 CAQM. CAQM monitors a wide range of anthropogenic and natural emissions; there are SO_2, NO_2, O_3, CO, and PM_{10}.

Similar to other ASEAN countries, the air quality in Malaysia is reported as the API. API system of Malaysia closely follows the PSI system of the United States. Four of the index's pollutant components (i.e., CO, O_3, NO_2, and SO_2) are reported in ppmv on the other hand PM_{10} is reported in $\mu g/m^3$. An individual score is assigned to the level of each pollutant and the final API is the highest of those 5 scores. To reflex the status of the air quality and its effects on human health, the ranges of index values is categorized as follows: good (0-50), moderate (51-100), unhealthy (101-200), very unhealthy (201-300) and hazardous (>300).Most of the time, API in Malaysia is always based on the concentration of PM_{10}.

EQR 2009 reported that, there was a slight decrease in the number of good air quality days recorded in 2009 (55.6 percent of the time) compared to that in 2008 (59 percent of the time) while remaining 43 percent at moderate level and only 1.4 percent at unhealthy level. It is estimated that, the combined air pollutant emission load was 1,621,264 metric tonnes of CO; 756,359 metric tonnes of NO_2; 171,916 metric tonnes of SO_2 and 27,727 metric tonnes of PM_{10}. There have a change of presenting air pollutants data in spatial from the wearisome numerical or literal form. The dispersion PM_{10} concentration, spatial PM_{10} mapping, was drawn by the IDW method. The results reveal that decreasing of estimation PM_{10} concentration with the increasing of the distance between the CAQM. The average of the dispersion of PM_{10} from year 2004 until 2008 is in the range of 44 – 54 $\mu g/m^3$. The maximum of the dispersion of PM_{10} concentrations from year 2004 until 2008 is about 112 – 118 $\mu g/m^3$. During the Northeast Monsoon and Southwest Monsoon, the mean are in the range 39 – 50 $\mu g/m^3$ and 52 – 60 $\mu g/m^3$ respectively. The maximum concentration of PM_{10} during Southwest Monsoon is 75 $\mu g/m^3$, whereas, during Northeast Monsoon the PM_{10} concentration is 58 $\mu g/m^3$. The intermediate monsoon period PM_{10} concentration is the highest value contribution of the PM_{10} concentrations to the maximum overall the year 2004 until 2008.

The different between the interpolated and in-situ monitoring PM_{10} concentration at the selected point have not differ by more than a factor of 2, thus, the IDW interpolation method can be used to describe the PM_{10} dispersion in Kuala Lumpur. Double reciprocal relationship formed between in-situ monitoring data and estimation IDW data with the correlation coefficient 0.289. Therefore, the IDW interpolation method is suitable for determining the air pollution status in areas which are not covered by the monitoring stations.

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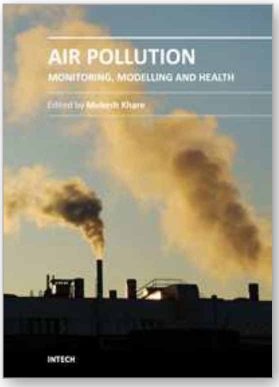

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Air pollution has always been a trans-boundary environmental problem and a matter of global concern for past many years. High concentrations of air pollutants due to numerous anthropogenic activities influence the air quality. There are many books on this subject, but the one in front of you will probably help in filling the gaps existing in the area of air quality monitoring, modelling, exposure, health and control, and can be of great help to graduate students professionals and researchers. The book is divided in two volumes dealing with various monitoring techniques of air pollutants, their predictions and control. It also contains case studies describing the exposure and health implications of air pollutants on living biota in different countries across the globe.

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