Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

PM_{10} EMISSION INVENTORY OF INDUSTRIAL AND ROAD TRANSPORT VEHICLES IN KLANG VALLEY, PENINSULAR MALAYSIA

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Published online: 15 January 2018

ABSTRACT

Rapid development in industrial and road transportation sector in developing countries has contributing the environmental issue. Determining the estimated PM_{10} emission in Klang Valley, Malaysia is based on the best available resources. Emission of PM_{10} from both sources was estimated particularly from numbers of industries (industrial area and emission factor) and the usage of motor vehicles (traffic volume, vehicle kilometer travel and emission factor). The PM_{10} emission from both industrial and road transportation sector were 88.59 tonne PM_{10}/year and 32.36 tonne PM_{10}/year respectively.

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doi: http://dx.doi.org/10.4314/jfas.v10i1s.21

Thus, the total estimated PM_{10} emission was 120.95 tonne PM_{10}/year. Therefore, the PM_{10} emission from both sources in Klang Valley can be estimated based on the best available resources due to limitation of actual PM_{10} emission from both sector.

Keywords: PM_{10} emission; emission factor; vehicle kilometer travel; industrial sector; road transportation sector.

1. INTRODUCTION

An aerodynamic diameter with less than 10 micron is the characteristic of the particulate matter (PM_{10}) [1] as the major air pollutant that contribute from road transportation activity [2], rapid development in industrialization and urbanization and thus producing serious issues toward environmental and public lifestyle [3].

The PM_{10} pollutant is originating from various emission sources such as mineral industries, construction sites, industrial heating boilers [4], agricultural operations, naturally windblown erosion from agricultural land that leads to dust suspension and traffic on road [5]. Other sources of PM_{10} are from cement industries emission, coal combustion power plants, biomass burning [3], secondary forming particles in the atmosphere and natural sea salt particles during drying of sea shore with the presence of dispersion agent like wind breeze [6].

Some researcher state that in urban cities the PM_{10} was emitted from road transport which can be separated into two main sources; exhaust (carboneous particles) and non-exhaust emission (tires, clutch, brakes wear and tear producing by-product of particulate) [7-8]. The PM_{10} emits from vehicular exhaust contain an organic compound (OC) that being derived from the primary emission sources and the OC can form the secondary PM_{10} emission sources via conversion of volatile organic compound (VOCs) into particles [3]. Besides, the road traffic activities also emit the re-suspension of dust to the atmosphere via active movement of vehicles in urban area [2].

High level of PM_{10} pollution is affecting not to mention to the environment but also has an impact to the public health causing variety of respiratory health problems such as lung diseases and lung cancer [6, 9], asthma and Acute Respiratory Infections and Influenza (ARII) [10] when public being exposed to the high level of PM_{10} pollution [11].

PM_{10} pollution also causing social impact to the public either local or interracial citizen via haze phenomena. Southeast Asia region including Malaysia over the past 30 years had encountered serious haze problem and had been spotted by researchers that the haze was originated from biomass and forest fires in Indonesia (Sumatra and Kalimantan) for agricultural land clearing causing the long-range transportation of pollutant, especially PM_{10}. This PM_{10} transboundary pollution has reduce the human visibility despite causing respiratory problem to the public [10].

Therefore, this study aim to determine the estimated PM_{10} emission from industrial and road transportation in Klang Valley, Malaysia under normal condition without haze scenario based on the best available resources which has been contributing the atmospheric pollution in this urban and metropolitan cities. The collection of information regarding the sources and contribution of PM_{10} to the air pollution [22-23] under limited resources forming the emission inventories has been the most preferable approach in most developing countries [11]. While in the developed nation like the European countries, conducting an emission inventories based on the best available technique and resources has been the most preferable approach for problem solving and corrective measures implementation in the integrated pollution and control (IPCC) program [12].

2. METHODOLOGY

2.1. Study Area

Klang Valley region is situated in the center of Kuala Lumpur and Putrajaya Federal territory adjoining several cities and towns of Selangor such as Klang, Shah Alam, Petaling Jaya, Gombak, Hulu Langat, Kuala Langat and Sepang. Klang Valley region is also be named as the Malaysia's heartland of industries and commerce due to rapid growth in industrialization, urbanization and population with total population in 2010 for Selangor, Kuala Lumpur and Putrajaya are 4.93 million, 1.44 million and 0.06 million reported by Department of Statistic [13].

2.2. Data Collection

Several data were collected and being utilized for this study. Land use of Selangor in 2013 from Town and Country Planning Department (JPBD) was used for the estimation of PM_{10} industrial emission based on area while the data set of Road Traffic Volume Malaysia from Ministry of Work (JKR) was use for the PM_{10} transportation emission estimation.

2.3. PM_{10} Emission Inventory

Estimation of PM_{10} emission from both sector; industrial and transportation by conducting the emission inventory is one of the method to determine the atmospheric emission. This emission inventory method in which applying the 'top-down' or 'bottom-up' approach has been commonly used by researcher [14]. The fundamental of 'top-down' approach is applying an information of total pollution over certain area of interest whereas the 'bottom-up' approach is applying the measured data set on ground over the area of interest. Emission inventories consist of compilation of annual value for each boundary which based on statistical data [15]. Thus, the characterization of the PM_{10} emission inventories was shown in Table 1.

Table 1. Characteristic of Klang Valley PM_{10} emission inventories [15]

Characteristics	PM_{10} Emission Inventories		
	Industrial	**Road Transportation**	**Total**
Domain	Klang Valley		
Spatial resolution	3 km x 3 km		
Spatial surrogate	Total industrial area	Road traffic volume and road network	Combined sources surrogation
Spatial data sources	Landuse 2013 (JPBD)	Road Traffic Volume Malaysia 2013 (JKR)	-
Temporal resolution	Annual		
Base year	2013		
Pollutant	PM_{10}		

2.3.1. Application of Emission Factor

Choosing an appropriate emission factor is essential in developing an emission inventory.

Emission factor is the universal approach that being used by researchers to estimate an emission from industrial and transportation sector in interpreting the air pollution [16].

2.3.2. Industrial Emission Estimation

In this stage, land use map of 2013 for Selangor from Town and Country Planning Department (JPBD) was used to determine the industrial area in Klang Valley in which parallel to the domain grid. The industrial area were classified into smaller grids within the domain grid. On the other hand, the emission factor for PM_{10} was calculated based on divided value of total PM_{10} emission load in Selangor obtained from Environmental Quality Report from Department of Environment (DOE) and the total industrial area in Selangor was obtained from the land use map of Selangor from Town and Country Planning Department (JPBD). The PM_{10} emission factor equation was shown below:

$$Emission\ factor, E_{f\ area} = \frac{Total\ emission\ load\ in\ Selangor\ (tonne/year)}{Total\ industrial\ area\ in\ Selangor\ (km^2)}$$

(1)

Finally, the obtained emission factor was used in multiplying the classified industrial area based on each individual grids in the domain with applying the following equation.

$$Emission\ area\ source, E_{A} = A_{ind\ in\ grid} \times E_{f\ area} \quad (2)$$

2.3.3. Transportation Emission Estimation

In this stage, the data set of Road Traffic Volume Malaysia of 2013 from Ministry of work (JKR) was used to determine the PM_{10} emission from the road transportation activities. The length of transportation access were used and segregated into three types of road segment such as highway, federal road and state road within each individual grid domain. The number of vehicles which had been classified into 6 different classes of vehicles within each individual grid and the emission coefficient for each vehicle classes as shown in Table 2 were used and applied in the following equation for quantifying the vehicle kilometer travel (VKT). The VKT is one of the available approaches with compiling input data and area of interest for calculating and establishing the emission inventories [17].

Table 2. Emission coefficient according to vehicle classes and road types

Vehicle Class	**Major State Road**	**Expressway**	**Emission Coefficient gPM_{10}/km** [18-19]
Class 1	Car/MPV/Van	2 axles (3 or 4 wheels- exclude taxis)	0.015
Class 2	Small lorry	2 axles (5 or 6 wheels- exclude buses)	0.083
Class 3	Heavy lorry	3 or more axles	0.252
Class 4	Taxis	Taxis	0.015
Class 5	Buses	Buses	0.291
Class 6	Motorcycles	-	0.018

The PM_{10} transportation emission equations using VKT are as follows [16-17]:

$$VKT_{Vehicle\ Class\ X} = Road\ segment_{grid} \times Traffic\ Volume_{Vehicle\ Class\ X} \quad (3)$$

$$E_{Vehicle\ Class\ X} = VKT_{Vehicle\ Class\ X} \times C_{Vehicle\ Class\ X} \quad (4)$$

$$E_{Transportation} = E_{Vehicle\ Class\ Xa} + E_{Vehicle\ Class\ Xb} + E_{Vehicle\ Class\ Xc} + E_n \quad (5)$$

where $E_{Vehicle\ Class\ X}$ = Total emission released by vehicle class X, $VKT_{Vehicle\ Class\ X}$ = Total vehicle kilometer travel by vehicle class X, $X_{C\ Vehicle\ Class\ X}$ = Emission coefficient of pollutant emitted by vehicle class X, Road $segment_{grid}$ = Total length or road in $3km^2$ grid, Traffic $Volume_{Class\ X}$ = Total vehicle count of vehicle class X and $E_{Transportation}$ = Total emission released by all vehicle classes.

2.3.4. Digital Data Generation and Statistical Modeling Using GIS

The Geographical Information System (GIS) technique involving statistical spatial distribution and interchange emission values to 3km x 3km gridding resolution was constructed due to solve the unspatially uniformity of the atmospheric pollutant emission. The pre-processing tasks such as geo-referencing, digitization and constructing an attribute database were conducted in the first place for achieving the integration of the calculated emission data into the GIS environment. The gridded emission value based on contribution of different sources lying inside each individual gridded cells then forming the separated emission for further analysis [16].

3. RESULTS AND DISCUSSION

The PM_{10} emission from the industrial and road transportation sources was estimated in this PM_{10} emission inventory which was based on the best available resources adapting both 'top-down' and 'bottom-up' approaches. Emissions of PM_{10} from industrial sector were estimated to be in the range between 0.0006 to 19.4152 tonne PM_{10}/year within the gridded domain. The overall PM_{10} emission for industrial area basis was estimated to be 88.5898 tonne PM_{10}/year and was shown in Table 3. The PM_{10} industrial emission was well illustrated in the PM_{10} industrial emission thematic layer interpolated by the Geographical Information System (GIS) application as shown in Fig. 1. From the PM_{10} industrial emission thematic layer it was shown that the major industrial emission area basis emission was spotted on the upper side of the gridded domain located in the Hulu Selangor district.

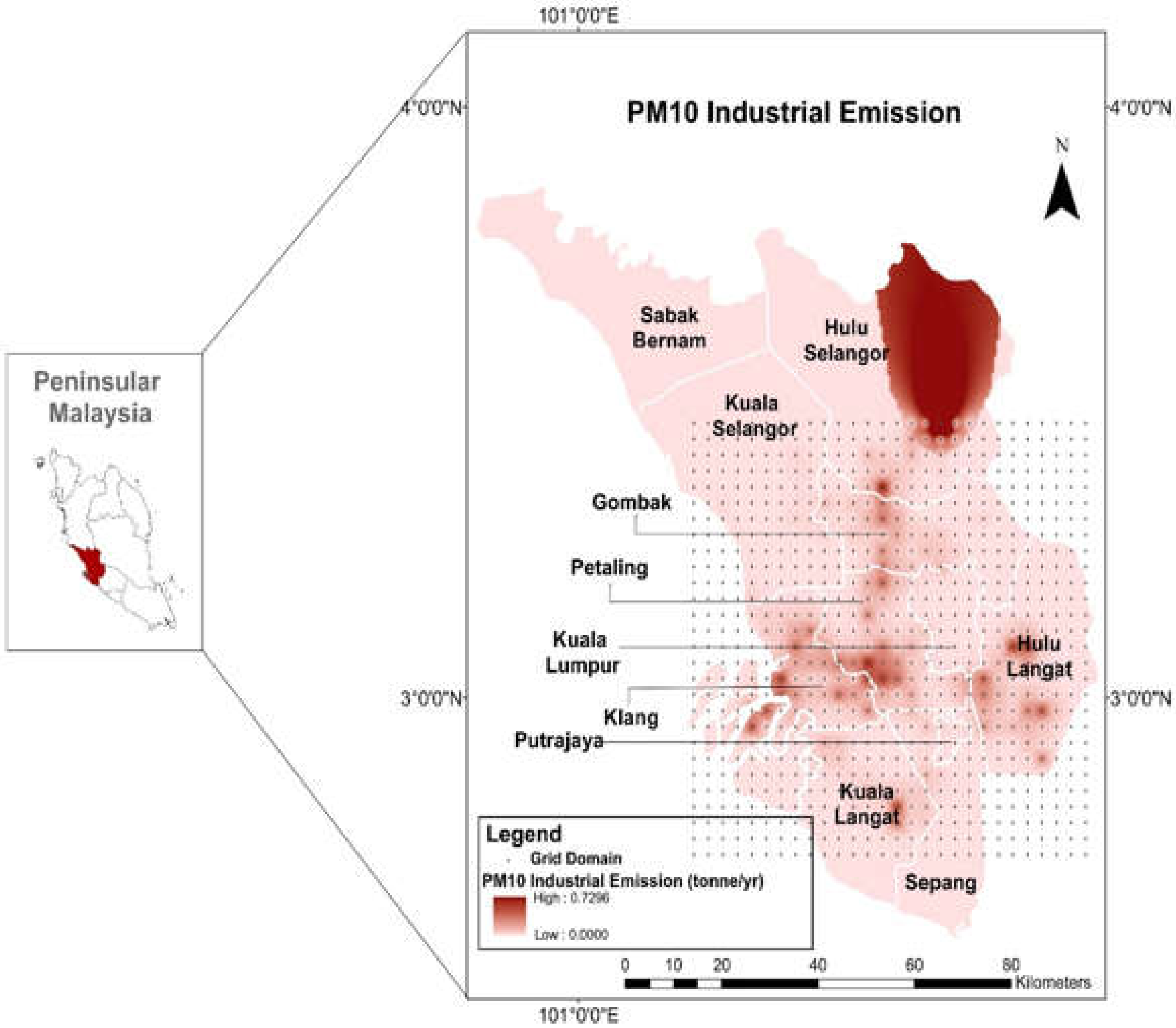

Fig.1. The PM_{10} industrial emission thematic layer

Emissions of PM_{10} from road transportation sector were estimated in the range of 0.0001 to 0.7497 tonne PM_{10}/year. The overall PM_{10} emission for road transportation sector was estimated to be 32.3590 tonne PM_{10}/year as shown in Table 3. The PM_{10} road transportations emission was best illustrated in the PM_{10} industrial emission thematic layer as shown in Fig. 2. The PM_{10} emission from road transportation sector was distributed and dense in the center part of gridded Klang Valley domain and it was based on the consideration of traffic volume for six classes of vehicles and three types of road. The possible PM_{10} emitted from vehicle exhaust were contributed to the resuspended of road particles due to incomplete fuel combustion [20]. The road particle also possibly originated from the wear of tires and brakes, soil and fraction of dried and decayed vegetative plant [21].

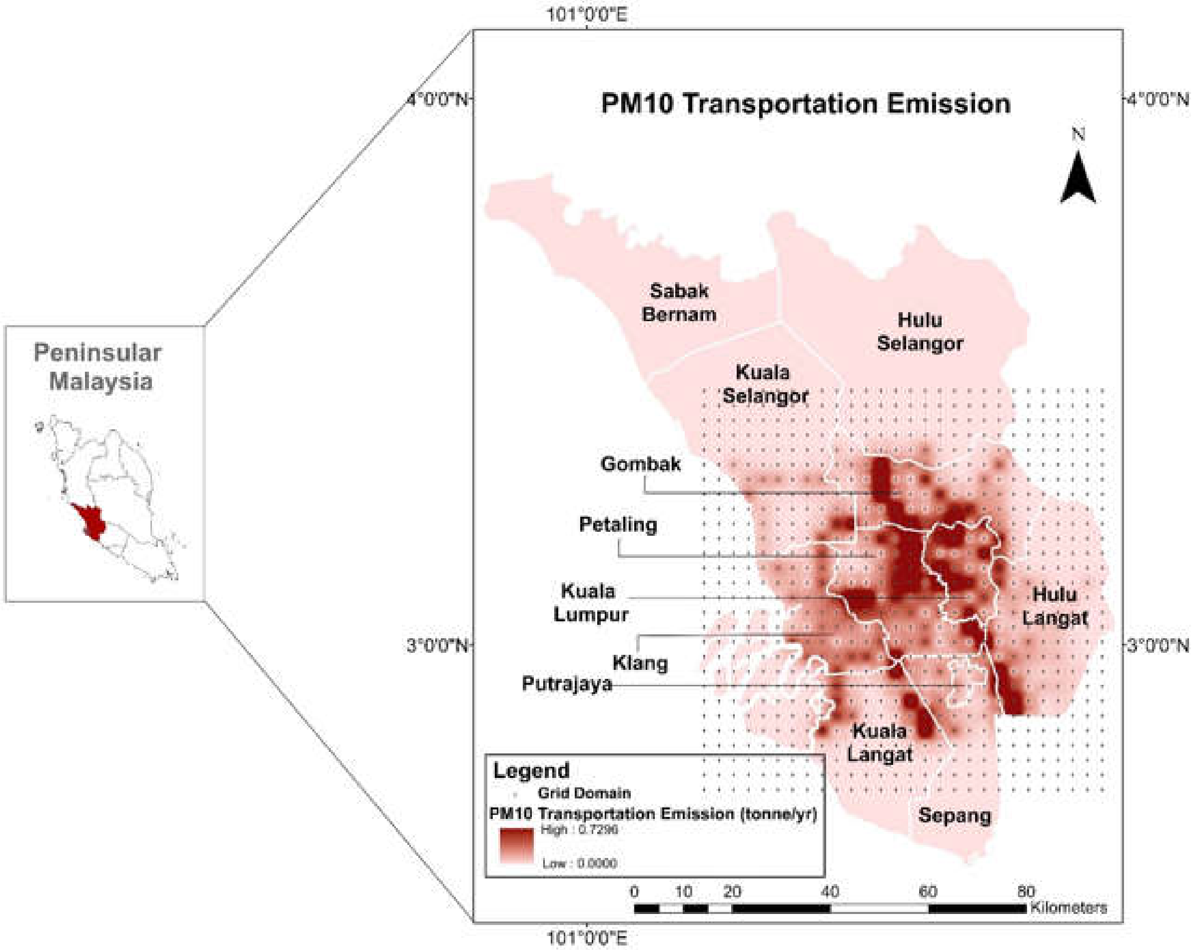

Fig.2. The PM_{10} transportation emission thematic layer

The total PM_{10} emission from both sources was estimated to be 120.9488 tonne PM_{10}/year as shown in Table 3 and illustrated in Fig. 3. The distribution of PM_{10} emission for total PM_{10} and industrial area basis emission were almost similar. The only difference was the distribution of PM_{10} was little dense in the center part of gridded domain due to combination of two emission sources.

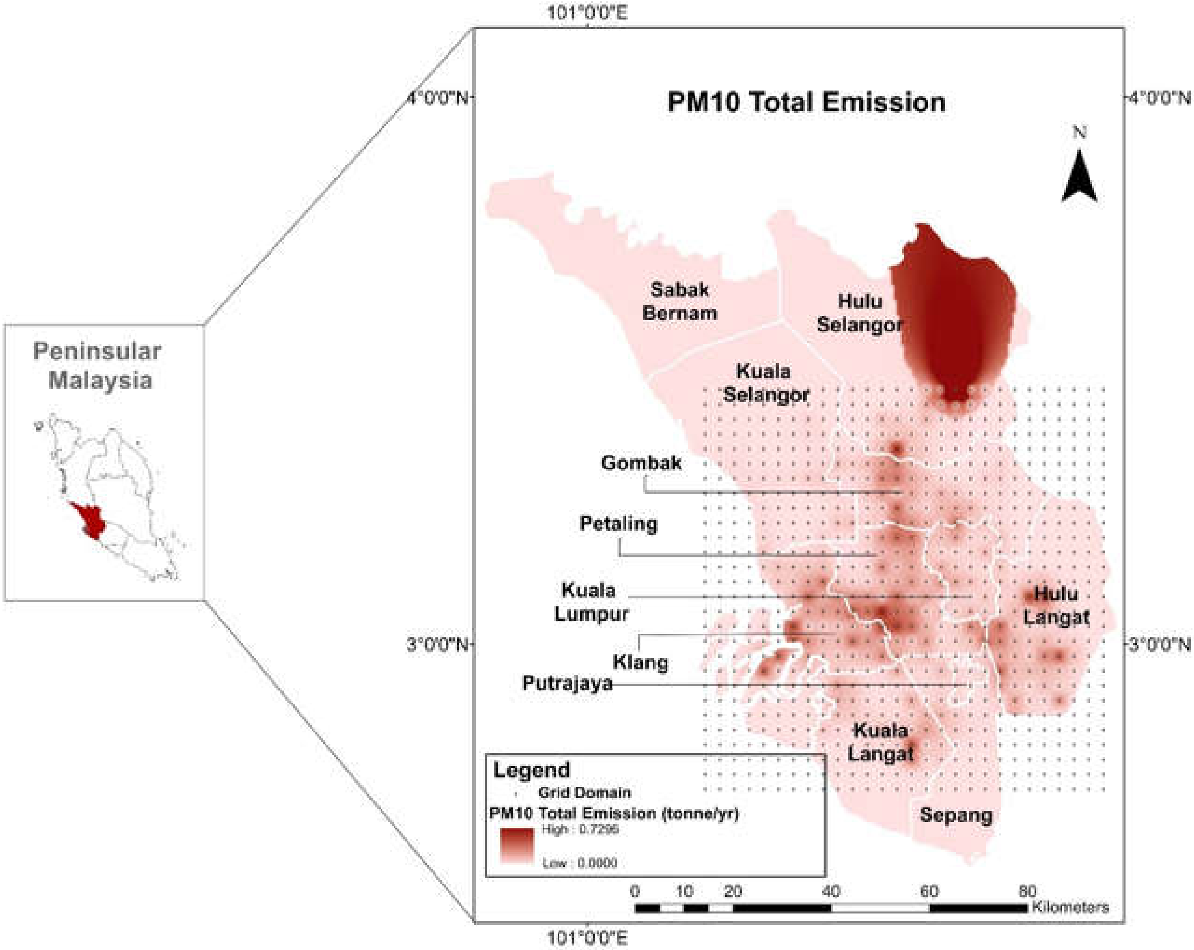

Fig.3. The PM10 total emission thematic layer

Table 3. PM_{10} emission inventory estimation based on the best available resources

Sources	PM_{10} Emission (Tonne PM_{10}/Year)		
	Minimum	Maximum	Total
Industries	0.0006	19.4152	88.5898
Road transportations	0.0001	0.7497	32.3590
Total emission	0.0001	19.4152	120.9488

4. CONCLUSION

High amount of PM_{10} emission were significantly proportional to the increase of industrial area and the number of vehicles on-road which resulted an increase of air and environmental pollution. Conducting the PM_{10} emission inventory from the industrial and road transportation sources in Klang Valley, Malaysia using the best available resources multiplying with the emission factor was the best approach to overcome the limitation on unavailability of actual PM_{10} emission data from both sector. Application of GIS was the most appropriate technique in interpolating the PM_{10} emission estimation from both emission sources; industrial and road transportation respectively.

5. ACKNOWLEDGEMENTS

Gratitude to Town and Country Planning Department (JPBD) and Ministry of Work (JKR) for providing us the Selangor land use map of 2013 and Road Traffic Volume Malaysia of 2013 data set for this study.

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How to cite this article:
Jamalani MA, Abdullah AM, Azid A, Ramli MF, Baharudin MR, Chng LK, Elhadi RE, Yusof KMK Ku, Gnadimzadeh A. PM_{10} emission inventory of industrial and road transport vehicles in Klang valley, peninsular Malaysia. J. Fundam. Appl. Sci., 2018, *10(1S), 313-324.*