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Research paper

Spatio-Temporal Analysis of PM_{10} in Southern Peninsular Malaysia

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Abstract

In this study, the particulate matter with diameter less than 10 micrometers (PM_{10}) is being observed. Other factors that influenced the pollutant dispersion are also being studied prior to identification of their relationship. The aim of this study is to identify the trend of PM_{10} concentrations in the Southern Peninsular of Malaysia during the period 2005 to 2015 by using spatio-temporal analysis in regards to air pollution. The inverse distance weighted (IDW) is used for the spatio interpolation data and mapping. The trends of the PM_{10} concentration are illustrated via map which indicates the affected and vulnerable area of Southern Peninsular Malaysia especially during Haze episode.

Keywords: *PM_{10}; haze; spatio-temporal; trend analysis*

1. Introduction

Air pollution is a major risk factor for non-communicable diseases (NCDs), causing cardiovascular disease, stroke and chronic obstructive pulmonary disease, as well as increasing the risks for acute respiratory infections (WHO, 2016). WHO (2016) has reported that about 3 million deaths were caused by ambient (or outdoor) air pollution in 2012. This is caused by emissions from traffic, industrial sources, waste burning or residential fuel combustion. While in 2014 nearly 90% of the populations in cities were exposed to fine particulate matter in concentrations exceeds WHO Air Quality Guidelines, with exposure rates varying considerably by region (WHO, 2016). Air pollution caused an estimated 6.5 million deaths, or 11.6% of all global deaths in 2012, making air pollution problem the biggest particular environmental health risk. Wang *et al.* (2017) reported that particulate matter pollution is a severe environmental issue in most regions in China due to the rapid growth of industrialization and urbanization sectors.

Particulate matter (PM) is one of the parameters measured in Air Pollution Index (API). PM is known as the dominant parameter in the API. This is because PM is the significant reason for the occurrence of air pollution (Fujii *et al.*, 2016). Besides that, the very tiny particles of PM have made it the most vulnerable to human health.

In Malaysia, there are inadequate studies on air pollution specifically on particulate matter especially at the Southern Peninsular which might be in serious issue as there were series of haze has been occurred based on the history that been recorded. In addition, the rapid growth in development especially industrial sector have influence the air pollution through anthropogenic activities. In a study by Sansuddin *et al.* (2011), there were about 22,971 industrial sources have been recorded by Department of Environment (DOE) and Johor have the utmost number of stationary sources by 35.4%.

The main challenge in analyzing air pollution is on the measurement and monitoring data as there are very few ground monitoring stations to cover a wide areas. Furthermore, having more on-ground monitoring station is still the best method to obtain the actual pollution status in that particular area. Therefore, the addition of monitoring station will enlarge the perseverance of the pollution data. Still, the cost of building a new monitoring station is high. Based on the study by Ibrahim *et al.* (2012), it is known that Alam Sekitar Malaysia Sdn. Bhd. (ASMA) claimed that one air monitoring station will cost about one million ringgit and it can only present an area within 15 km radius. Besides, the operating cost of a monitoring station is very expensive which is why there is a small number of monitoring stations throughout the states (Jamil *et al.*, 2011). Therefore, in order to overcome this problem, spatio-temporal analysis helps to identify the area that was not covered by monitoring station. Spatio-temporal analysis works by using the method of inverse weighted distance (IDW) in Geographic Information System (GIS).

The main objective of this paper is to establish a spatio-temporal analysis of PM_{10} concentration to study the trend analysis of the pollutant throughout the years (2005 – 2015).

2. Materials and Methods

2.1. Study Area

Since the availability of the data is limited, this study focused on the states of Johor with four municipalities which are Muar, Larkin, Pasir Gudang and Kota Tinggi (Figure 1 and Table 1). All the municipalities vary with socioeconomics condition such as industrial sources, palm oil factories and residential areas.

Fig. 1: Monitoring stations in Johor (Muar, Larkin, Pasir Gudang and Kota Tinggi.

Table 1: Coordinates of the monitoring stations in Johor

Longitude	Latitude	Places
102.593117	2.061917	Muar
103.72695	1.496917	Larkin
103.89395	1.470417	Pasir Gudang

2.2. Data Source

PM_{10} concentrations data were obtained from the Department of Environment (DOE) Malaysia from the ground monitoring stations located all over the states. The concentration is recorded for the duration of 10 years (Table 2) from 2005 until 2015.

Table 2: Annual average PM_{10} concentrations ($\mu g/m^3$)

Years	Muar	Larkin	Pasir Gudang	Kota Tinggi	PM_{10} concentration ($\mu g/m^3$)
2005	54	36	47	-	
2006	54	56	49	-	
2007	42	55	45	-	
2008	48	40	53	42	
2009	53	44	58	50	
2010	50	42	50	45	
2011	51	44	45	47	
2012	44	41	53	87	
2013	47	44	51	49	
2014	48	45	50	39	
2015	55	60	65	48	

2.3. Interpolation of Data

PM_{10} concentrations are recorded at the monitoring-station level. However, because of the irregular scatterings of the monitoring stations, the concentrations at the gap of monitoring stations remain unidentified. Therefore, by applying spatio interpolation techniques to the available monitoring data, the air quality information between monitoring stations could be acquired (Brereton *et al.*, 2011). There are several techniques that are involved in interpolation which are inverse distance weighted (IDW), kriging, spline and natural neighbour.

IDW has been chosen as the technique that was used because its interpolation works by estimating cell values by averaging the values of sample data points in the neighbourhood of each processing cell (Shareef *et al.*, 2016). Besides that, IDW is the common practice technique that has been used. Hence, IDW methods are suitable for this project.

3. Results and Discussion

3.1. PM_{10} Graph Distribution

Figure 2 shows the distribution of the annual average PM_{10} concentrations in a graph form for the four municipalities in states of Johor. These four municipalities are diverse in socioeconomic as Muar is a rural area, Larkin is an urban area, Pasir Gudang is an industrial area and Kota Tinggi is a suburban area.

The limit of the annual average PM_{10} concentration is $50\mu g/m^3$ which is set by DOE (DOE, 2013). Hence, any concentration readings beyond the limit are considered unhealthy. From the year 2009 until 2011, it showed that PM_{10} concentrations in Muar were worse than Larkin even though Larkin was more condensed than Muar. This is due to the haze episode that happened on that time. The wind has brought the smoke from the forest burning in Sumatra, Indonesia and caused a transboundary issues. This transboundary has caused district of Muar to be declared in state of Haze Emergency. Several schools were closed due to this problem. In 2012, PM_{10} concentration at Kota Tinggi has skyrocketed to $87\mu g/m^3$ beyond the limit and highest compared to the other three municipalities. It is known that the transboundary issues happened and affected the concentration in Kota Tinggi due to the forest fire in Central and Northern Sumatra, Indonesia.

The Federal Government of Malaysia has gazette the Environmental Quality (Clean Air) Regulations 2014 to replace the Environmental Quality Act 1974 (Jabatan Alam Sekitar, 2014). There are many regulations that industrial sectors need to comply in order to ensure the environment is preserve. Therefore, in the year 2014 Pasir Gudang shows a decrease in the PM_{10} concentrations as part of the compliment to the new regulations.

It can be seen that even though more concentrations seems to be below the limit throughout the 10 years period, however on year 2015 the concentrations for all places are increased. This is due to the haze period that happened in Malaysia from August to September because of the massive land and forest fires in Sumatra and Kalimantan, Indonesia. During this time, many schools were closed since the air qualities were in the very bad conditions.

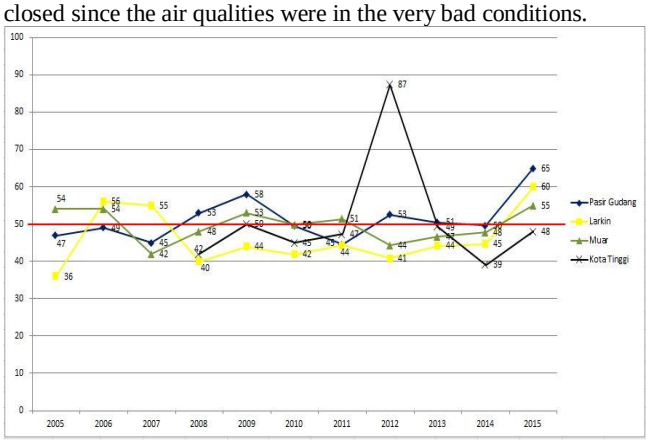


Fig. 2: Graph distribution of annual average PM_{10} concentrations

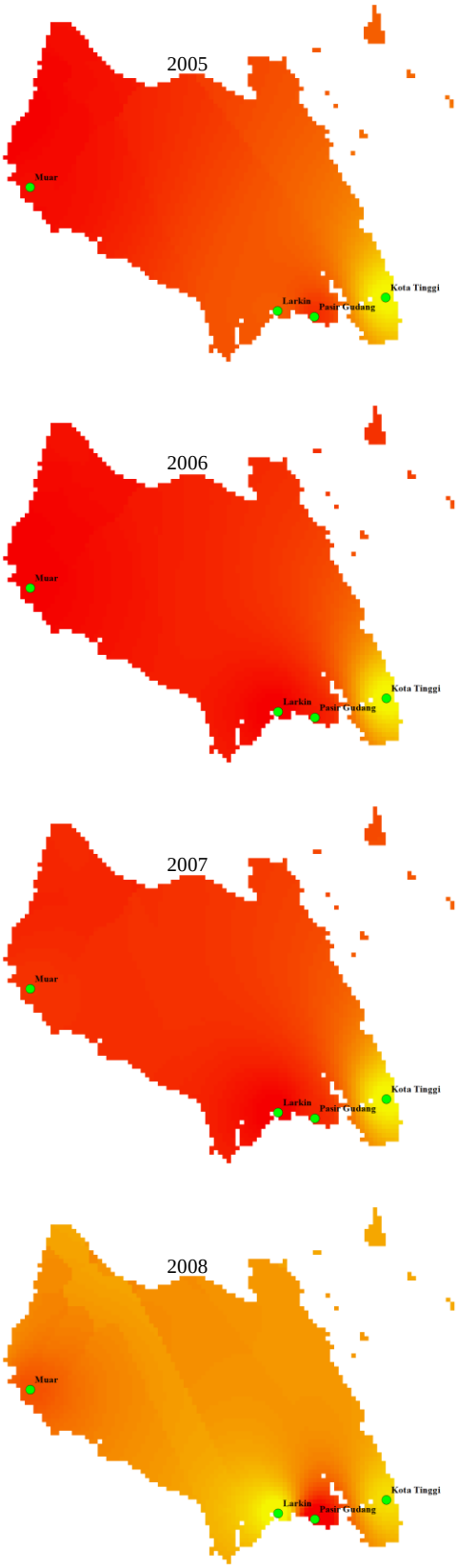
3.2. PM_{10} Spatiotemporal Distribution

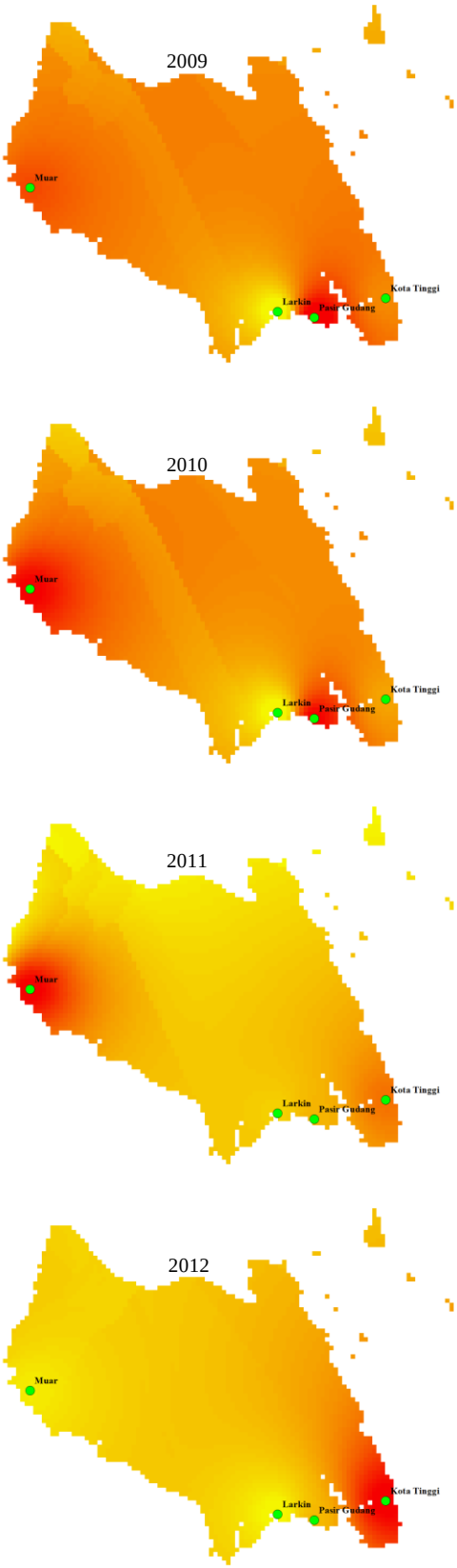
Figure 3 shows the mapping of annual average of PM_{10} concentrations in states of Johor during the 10 years period of 2005 to 2015. These mapping are done using the spatio-temporal analysis by interpolate the data.

Based on the mapping, the west and central of Johor have concentration above the limit from the year 2005 until 2007 and 2014 to 2015. This mapping is significant with the neighbouring stations (Muar, Larkin, Pasir Gudang and Kota Tinggi). It is generated by the estimation of the neighbouring station values to the uncovered area. Due to the transboundary haze that occurred, the uncovered area also affected. Hence increase the reading of the concentration in the uncovered area. Besides the transboundary issues, the local

pollution also contribute to the significant increase of the PM_{10} concentrations.

As of 2015, the affected area due to the pollution is covered in a vast area all over the states. Massive land burning in Indonesia contributed to the smog and haze that happened in states of Johor. As the haze happened during monsoon season, it was influenced by wind direction. Because of this, the winds are likely to circulate around the atmosphere of the Southern region. Therefore the concentrations of PM_{10} rose quickly.





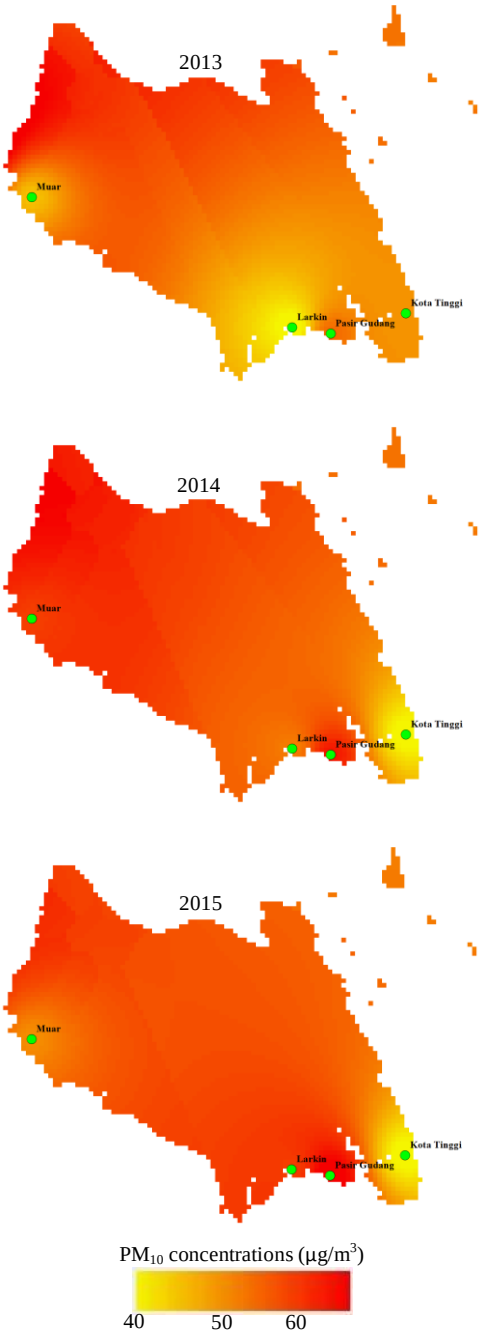


Fig. 3: Mapping of annual average PM_{10} concentrations

4. Conclusion

Air pollution is a serious problem to the country especially in the developing country. As particulate matter is the dominant parameters in Air Pollution Index (API), this study shows that this parameter can become more hazardous and harmful because of the development growth rapidly.

Throughout the 10 years only two years which are 2011 and 2012 did not experience transboundary haze. Hence, only the local pollution that contributed to the PM_{10} concentration readings. Thus, this transboundary problem plays a big role in affecting the air quality of a country.

Moreover, the area that did not have any monitoring stations, the readings still can be estimated. With the help of spatio-temporal analysis, the uncovered area can be predicted.

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