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Research paper

Time Series Analysis of PM_{10} Concentration in Parit Raja Residential Area

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Abstract

Parit Raja is one of the sub-urban area that rapidly grow due to its location containing industrial and education hub. Pollution from factories and the increasing number of vehicles are the main contributors of PM_{10}. Since PM_{10} can give the adverse effect to human health such as asthma, cardiovascular disease and lung problem, appropriate action mainly involve short-term prediction maybe required as a precaution. This research was conducted to predict the PM_{10} concentration using the best time series model in Parit Raja, Batu Pahat, Johor. Primary data was obtained using E-Sampler at three monitoring stations; Sekolah Menengah Kebangsaan (SMK) Tun Ismail, Kolej Kediaman Melewar and Sekolah Rendah Kebangsaan Pintas Raya. ARIMA time series model was used to predict the PM_{10} concentration and the most suitable model is identify using by Akaike Information Criterion (AIC). Prediction of PM10 concentration for for the next 48 hours at all monitoring locations was verified using three error measures which are mean absolute error (MAE), normalized absolute error (NAE) and root mean square error (RMSE). After comparing the time series model, the short term prediction model for station 1 is AR(1), station 2 is ARMA(1,1) and station 3 is ARMA(2,1) based on the smallest AIC value and the best time series model that used for prediction at Parit Raja residential area is AR(1). Since the best model was identified for Parit Raja residential area, PM_{10} concentration can be predicted using AR(1) model to identify the value of PM_{10} concentration in the next day.

Keywords: *Use Antifungal, indoor air contamination, indoor air quality, plasterboard, wall finishing.*

1. Introduction

Nowadays, one of the major environmental problems in Malaysia is air pollution. The pollutants in ambient air reduce the air quality level in the polluted area as well as its surrounding areas in which it depends on the wind speed and wind direction. The low air quality level can cause harmful effects to human health especially to children, the elderly and people with respiratory problem. As one of the developing countries, air pollution level in Malaysia will increase due to urbanization and due to the increasing number of vehicles used by the residents living in Malaysia. In a study conducted by Afroz *et al*. [1], it was established that the main source of air pollution in Malaysia is mobile sources (82%) followed by power station (9%), industrial fuel burning (5%), industrial production processes (3%), domestic and commercial furnace (0.2%) and open burning solid waste at disposal site (0.8%).

United State Environmental Protection Agency (EPA) [2] divided particulate matter into two categories which consists of fine and coarse particle. Particulate matter with size of 2.5µm and below (also known as $PM_{2.5}$) is a fine particle where the particles are disperse, cannot be seen in air, move freely over long distance and it can be suspense in the air for a long duration. For coarse particle, its size particle can be referred between 2.5µm to 10µm or it is dark enough to be seen as smoke or it can be small and can only be detected by using an electron microscope.

In Malaysia, the government agency that is responsible for monitoring the air quality level is the Department of Environment. There are 52 monitoring stations located all around Malaysia. For instance, in Johor, the Department of Environment has placed 4 stations which are situated in Kota Tinggi, Larkin Lama, Muar and Pasir Gudang. Larkin and Pasir Gudang are categorized as an industrial area while Kota Tinggi and Muar are categorized as urban and sub-urban area respectively. The Department of Environment monitors the air quality based on five main pollutants which is Particulate Matter ranging in size from 2.5 to 10 micrometer in aerodynamic diameter (PM_{10}), sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2) and carbon monoxide (CO).

This study was concerned with the coarse particle that ranges in size from 2.5 to 10 micrometer (PM_{10}) as previous studies have shown that particles larger than 10µm did not penetrate the body's defenses in nose, mouth and upper airways so it is unlikely to cause respiratory effects [3]. Table 1 presents the detail of Malaysia Ambient Air Quality Guideline (MAAQG) for PM_{10} concentration. Based on Table 1 the limit of PM_{10} concentration in Malaysia with an average of 24 hours is 150µm/g3 whereas for 12months the average is 50µm/g^3.

Table 1: Malaysia Ambient Air Quality Guideline for PM_{10} concentration

ollutant type	Averaging time	Malaysia Guideline $(\mu g / m^3)$
Particulate Matter (PM_{10})	24 hour	150
	12 month	50

Statistical analysis of PM_{10} concentration such as measures of location will provide basic information but for the purpose of prediction, further analysis should be conducted. This study is focused on the short-term prediction of PM_{10} concentration in Parit Raja residential area using time series analysis. In an annual report provided by Department of Environment [4] had indicated that the main contributor for PM_{10} concentration are motor vehicle exhaust, heat and power generation plants, industrial process and also open burning activity.

Therefore, this study aims to develop time series analysis model about concentration of PM_{10} in Parit Raja residential area and to predict the future concentration of PM_{10} pollutant. There has been an excessive use of motor vehicles due to the rapid growth of population in Parit Raja which also includes the students from UTHM. The data from Department of Statistics Malaysia had indicated that the number of population in Parit Raja have increased from 14901 person in 2000 to 18618 person in 2010 (not include UTHM students). Apart from the increasing of motor vehicles, the other source of PM_{10} at Parit Raja arises from the industrial sources. Physical observation has shown that one of the industries has the frequent production of plume. This may contribute to the high level of PM_{10}, in which will affect the health.

2. PM_{10} Concentration and Effect to Human Health

Malaysia is one of the successful developing countries in the world. By 2020, Malaysia targets to achieve the status of being an industrial country as well as the status for having a rapid economic growth having started to impose cost in-term of environment. In Malaysia, air pollution is one of the major issues that has been affecting human health, agriculture crops, forest species, and ecosystem [1].

A wide range of studies have been conducted on relation of PM_{10} and health effect. Afroz et al. [1] in a review research had established the effects of PM_{10} during the worst haze episode in Malaysia in 1997. It had increased the impact to human health such as an increased of hospital visit, asthma attack, chronic bronchitis and others. In 2013, during the haze crisis, the Selangor residents mostly those situated in Banting and Shah Alam suffered with acute respiratory problem [5].

The PM_{10} would also affect human organs and bodies. Additionally, the PM_{10} pollutant would provide major effects to cardiovascular system, respiratory system, nervous system, urinary system, digestive system and exposure during pregnancy [6]. During the haze episode, various respiratory problem including bronchitis and emphysema had mostly affected human health [7]. While the effects from the cardiovascular caused by the PM_{10} pollutant to human health would increase the mortality rate [8].

The population would increase the PM_{10} concentration at the atmosphere and the adverse effect will affect human health especially at dense population area and it will increase health problems such as asthma and hospital visit in China [9]. The increasing and decreasing of PM_{10} concentration have revealed how it affects human health. Increasing of $1\mu m/g^3$ of PM_{10} would cause an increase of asthma cases by 28.2%. However, Glorennec and Monttroux [10] stated that decreasing 10% of PM_{10} pollutant will reduce the number of expected death to 19% for short term exposure in Caen, France.

3. Time Series Modelling

Time series analysis involves the statistical methodology of the analysis of a sequence of data [11]. The basis of the modeling time series consists of three phases which is identification, estimation and testing [12]. There are several time series studies conducted to make prediction of the pollutant trends in various areas. This section will focus on the previous researches related to time series analysis of PM_{10} concentration.

In forecasting air pollution especially in the PM_{10} pollutant in time series have been conducted by several researchers. The prediction of air quality index in Selangor indicates that there are two suitable models which are ARIMA (3, 1, 3) and AFRIMA (0, -0.5, 2) [13]. To compare between these two models, the best model is the AFRIMA (0, -0.5, 2) as it provides the best prediction whereas ARIMA (3, 1, 3) is not able to forecast the actual value of air quality for instance in September 2003 it was found to be below the 95% lower bound of the interval.

Time series analysis has been used to predict the Ozone (O_3) concentration in Kemaman, Terengganu. The result demonstrates the long term prediction for ozone concentration is ARIMA(0,1,1)(1,1,2)12 as a successful prediction to apply in Kemaman, Terengganu [14]. The time series analysis was developed from 144 reading data taken from Automatic Air Quality Monitoring System in kemaman station in period from 1996 to 1997.

Sansuddin *et al.* [11] concluded the best time series model for four different locations. Industrial represent at stations located in Johor Bharu and Nilai and residential represent at stations located at Kota Kinabalu and Kuantan is AR(1). This model of AR(1) has been found suitable for all monitoring location after the secondary data from 2000 to 2003 was provided by DOE and have been analyzed using time series forecasting.

4. Methodology

4.1. Data and Study Area

This research was conducted at Parit Raja residential area at three selected monitoring stations which was Station 1 at SMK Tun Ismail, Parit Raja, Station 2 at Melewar residential college and Station 3 at SK Pintas Raya, Parit Raja. The instrument that was used to collect data of PM_{10} concentration is e-sampler. The details of the location are shown in Figure 1 while the summary of monitoring stations is shown in Table 2. The monitoring station was selected due to surrounding residential area.

4.2. Descriptive Statistics

The descriptive statistics can be defined as the numbers that are used to summarize and describe of data [16]. The descriptive statistics that used in this study is mean, mode, median, skewness, standard deviation and box plot.

4.3. Time Series Analysis

The aim of this studies to determine the best model for prediction of PM_{10} concentration in Parit Raja residential area. In order to determine the best model, there are time series procedures that need to follow such as below:

Fig.1: Location of monitoring stations

Table 2: Location of monitoring station

Station	Location	Coordinate
Station 1	SMK Tun Ismail, Parit Raja	$(1^{\circ}52^{'}03.9''N, 103^{\circ}06'45.1''E)$
Station 2	Melewar Residential College	$(1^{\circ}51^{'}08.9''N, 103^{\circ}06'03.1''E)$
Station 3	SK. Pintas Raya, Parit Raja	$(1^{\circ}50'51.7''N, 103^{\circ}04'18.3''E)$

4.3.1 Time Series Plotting

The first and most important step in any time series analysis is to plot the observation against times [11] By plotting the time series data, provides a basis for postulating a possible data transformation [15].

4.3.2 Stationarity

The stationarity determination using the time series plot is very subjective. The most common test that used to identify the stationarity in time series analysis by used the Augmented Dicky-Fuller test (ADF). The following regression uses in the ADF test [14]:

$$\text{ADF} = \alpha_0 + p_1 y_{t-1} + \sum_{j=2}^{p-1} \beta_j \nabla y_{t-j} + e_t \qquad (1)$$

Where,

α_0 : Drift Component

e_t : Independent and homogeneous error term

H0 : Null hypothesis note as time series data is non-stationary and can be rejected by two condition which is: (1) ADF value is smaller than the ADF critical value and (2) the significance level (p) is smaller or equal to 0.05.

4.3.3 Identification

To identify the order p and q, the sample of autocorrelation function (ACF) and partial autocorrelation function (PACF) of the properly transformed and differ enced series will be compute and examine, where p is the highest order in autoregressive polynomial and q is the highest order in the moving average polynomial and these order need p and q are less than or equal to 3 [15]. The simple model shown in Table 3 given by Janacek [18] can be used as guide. If the autocorrelations are zero after laq q, the model appropriately has an MA(q) process while if the decay is exponential the model is AR(p) model. The correlations are expected to tail off after lag (p – q) for the mixed model ARMA(p,q).

Table 3: Behavior of the auto and partial correlation function

Process (Model)	Autocorrelation Function (ACF)	Partial Autocorrelation Function (PACF)
AR(*p*)	Exponential decay	Zero after lag *p*
MA(*q*)	Zero after lag *q*	Exponential decay
ARMA(*p*,*q*)	Exponential decay after lag (*p* - *q*)	Decay after lag (*p* – *q*)

4.3.4 Estimation

According to Sansuddin *et al.* [11], there have two steps to complete the estimation phase. First step is to determine the model order by used the computation of the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC). The second step to decide if the model fitting is complete or if it needs to be pursued further by using the residual computations. The model of AIC and SBC are model selection based on residual [19]. Jalil and Mahmud [19] also stated, in selecting of the smallest possible lag length, the SBC will be used where it is also known as parsimonious model or simple model while the AIC will be used to selecting and determine the maximum relevant lag length. The basic equation for AIC is stated below:

$$AIC = 2k - 2\ln(L) \tag{2}$$

Where,
k: Number of estimate parameter in the model.
L: Maximum values of the likelihood function for the model.

4.3.5 Prediction

The main objective for modeling a time series is to make a forecast. Assumption that the parameters of the fitted model are known exactly for forecasting purpose and in practice only estimates will be available [20]. According to Chatfield [21], a univariate forecasting method is a procedure for computing a point forecast, based only on past and present values of the given series (possibly augmented with a function of time such as a linear trend). For example, the observation on a single time series denoted by x1,x2,…,XN and wish to forecast XN+h for h = 1,2,…. Chatfield (2000) claimed the basic model based forecasting expression as follows:

$$\hat{X}_N(h) = E(X_{N+h} | M, I_N) \tag{3}$$

4.3.6 Verification

In this study, to judge the developed model some of the performance indicator has been used. Three performance indicators that have been used in this studies is mean absolute error (MAE), normalized absolute error (NAE) and root mean square error (RMSE). Junninen *et al*. [22] stated that, the smallest value of error indicate the appropriate model.

4.3.7 Missing Values

Missing data can be described as in complete data matrices. The widely used to replace missing value is mean above below method. The mean of the point between above and below missing gap is compute to get the replace value [23].

5. Results and Discussion

The results and discussions in this study are divided into three parts which is PM_{10} characteristics using the descriptive statistics, behavior of PM_{10} concentration which illustrate using bar chart and the last part is time series analysis.

5.1 Descriptive statistics

The details of descriptive statistics for the actual monitoring records is provided in Table 4. The highest mean is 14.675 recorded at station 1 (SMK Tun Ismail) followed by station 2 (Melewar Residential College) and station 3 (SK Pintas Raya) with mean value 10.968 and 9.601 respectively. Station 1 has high dispersion of concentration with the value of standard deviation is 17.001 and also the highest value of skewness compared to other stations. This is due to traffic congestion and local community activity such as burning and the use of vehicles. The distribution of monitoring records at all three stations are positively skewed which means that most of the monitoring records is lower than the mean.

Table 4: Characteristic of PM_{10} concentration in all stations

	Station 1 (SMK Tun Ismail)	Station 2 (Melewar Residential College)	Station 3 (SK Pintas Raya)
Number of Data, N	212	218	240
Mean	14.675	9.601	10.958
Median	11.000	9.000	10.500
Mode	9.000	7.000	12.000
Standard Deviation	17.001	3.537	4.065
Skewness	6.101	0.839	1.742

Box and whisker plot was used to show and display patterns of monitoring records. The box and whisker plot for all three monitoring stations are illustrated in Figure 2. From the box and whisker plot it is identified that the major of outlier was recorded at station 1 followed by station 3 while for station 2, there are no outliers of monitoring records. The highest outlier value of the concentration is $170\mu g/m^3$ observed at station 1. The value of monitoring records in all three stations has almost similar based on the Box and Whisker Plot.

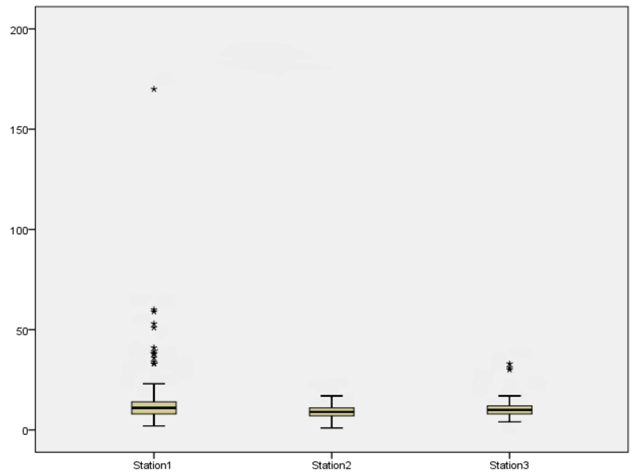

Fig. 2: Box and whisker plot for all stations

5.2 Behaviour Analysis of PM_{10} Concentration

The summary of monitoring records in average for each hour for all three stations is shown in Figure 3, Figure 4 and Figure 5. Based on all three bar charts, the highest value of PM_{10} concentration with $31\mu m/g^3$ and $30\mu m/g^3$ occurred at time 11.00am and 04.00pm at Station 1 most probably caused by traffic congestion. During 11am to 4pm, the psychical observation suggests that there was transition between school session from morning to noon which indicate an increased on vehicles at that area. In a previous research conducted by Wang *et al*. [24], the concentration of PM_{10} influence the mobile source which includes cars, motorcycles, lorries and others especially at congested road, while Shi *et al*. [25] found that the 36%-44% of the particle less than 10µm accounted from mobile sources in urban atmosphere.

Based on the three bar charts, it displayed the increasing of PM_{10} concentration at station 1 starting at 7.00am with $11\mu m/g^3$ and reached its peak at 11.00 am with concentration of $31\mu m/g^3$ and decreased of concentration at 4.00am at value $16\mu m/g^3$. For Station 2, the peak value of PM_{10} concentration is $13\mu m/g^3$ occurred at 9.00pm when it starts to increased at 8.00pm with concentration $10\mu m/g^3$ and decreased to $7\mu m/g^3$ of concentrations at 2.00pm. While at Station 3, the increasing trend start with value of PM_{10} concentration is $11\mu m/g^3$ at 6.00pm and decreased start with value of $10\mu m/g^3$ at 2.00pm after achieve the peak concentration at 9.00am with value of concentration of $14\mu m/g.^3$

In summary for hourly average PM_{10} concentration, the bar chart presents the value of concentration of PM_{10} is much higher during the night than day. This result is similar to a study conducted by

Vechhi *et al.* [26] on the difference in PM_{10} concentration at daytime and nighttime, where it was stated that the strong stability of atmosphere occurring frequently from late afternoon to late morning causes PM_{10} concentrations to be higher during the night than during the day even if the sources of emissions strongly reduce their contributions. Beside of temperature condition, mixing height is also one of the contributors that cause the reading of PM_{10} to be highest at night compared to day. Mixing height at night and morning are lower compared to mixing height at noon. Nevers [27] stated that the concentration of pollutant is reduce when the mixing height layer is high (Usually at noon) while the reducing of mixing height layer will increase the pollutant concentration.

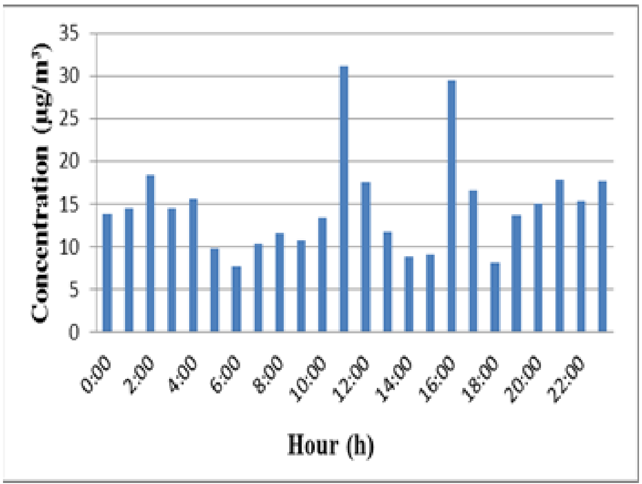

Fig. 3: Bahaviour of PM_{10} concentration for station 1

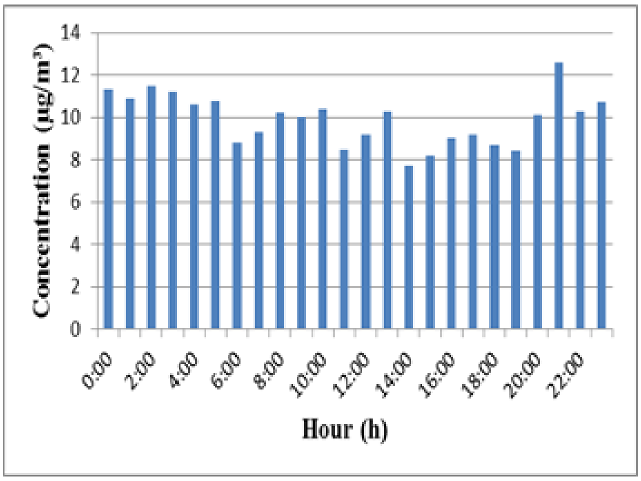

Fig. 4: Bahaviour of PM_{10} concentration for station 2

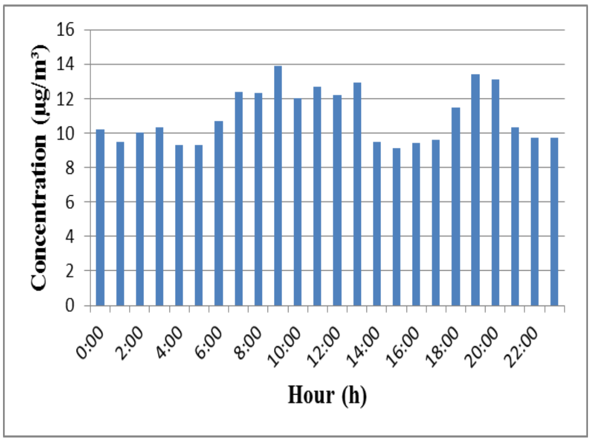

Fig. 5: Bahaviour of PM_{10} concentration for station 3

5.3 Time series analysis

The first and most important in time series analysis is to develop the time series plot to determine the stationarity of the data, but sometimes the time series plot is very subjective and the Augmented Dicky Fuller test (ADF) needs to be executed as a second test to determine the stationarity of the data. Table 5 displays the summary of ADF test and model selected in each station based on the lowest AIC value. From Table 5, all the three stations were determined as stationary since the significance value of ADF test and model selected in each station based on the lowest AIC value. From Table 5 also, all the three stations were determined as stationary since the significance value of ADF test is lowest than 0.05. The next step is identification of model in each station based on the lowest value of Akaike Information Criterion. The suitable model for Station 1 is AR(1), ARMA(1,1) for Station 2 and ARMA(2,1) for Station 3.

Since the suitable model in each station was identified, the equation from each model has been produced and it will be used to predict the value of concentration of PM10 in each station. When the predicted value was obtained based on the equation, the validation process was conducted based on the performance indicator. The performance indicator that was used in this study was normalized absolute error (NAE), mean absolute error (MAE) and root mean absolute error (RMSE). To provide general indications of the relationship between the observed data and the predicted data, this performance indicator has been applied by several researchers [28]. The summary of performance indicator and equation in each station is shown in Table 6.

Table 5: Summary of ADF test, best time series model and AIC value for all monitoring stations

Station	ADF Test	Significance Value	Stationarity	Best time series model	AIC Value
Station 1	-10.500	<0.001	Stationary	AR(1)	8.6492
Station 2	-4.840	<0.001	Stationary	ARMA(1,1)	4.9878
Station 3	-10.869	<0.001	Stationary	ARMA(2,1)	5.6258

Table 6: Equation and result of performance indicator for all monitoring stations

Station	Best time series model	Equation	Performance indicator		
			RMSE	MAE	NAE
Station 1	AR(1)	$y_t = 15.535 - 0.308 y_{t-1} + \varepsilon_t$	5.1898	4.1736	0.3756
Station 2	ARMA(1,1)	$y_t = 10.095 - 0.821 y_{t-1} + 0.388 \varepsilon_{t-1} + \varepsilon_t$	3.0181	2.2735	0.2556
Station 3	ARMA(2,1)	$y_t = 10.847 - 1.349 y_{t-1} + 0.409 y_{t-2} + \varepsilon_{t-1} + \varepsilon_t$	3.0096	2.4399	0.2153

The graph actual and predicted value has been developed after the determination of equation. Figure 6 to Figure 8 shows the graph of actual value and predicted value of PM_{10} concentration based on best time series model in each station.

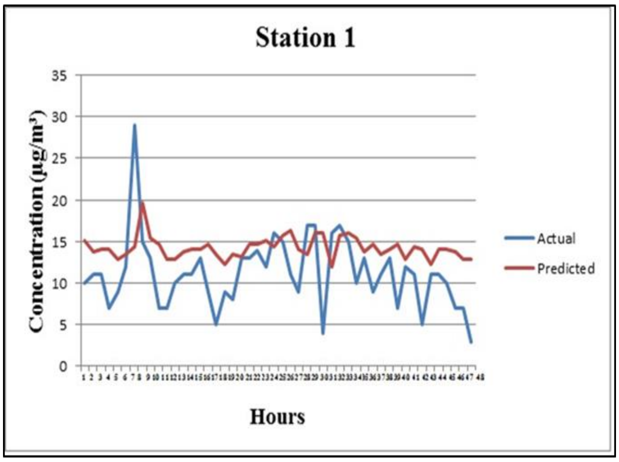

Fig. 6: Graph of actual and predicted value of PM_{10} concentration for Station 1

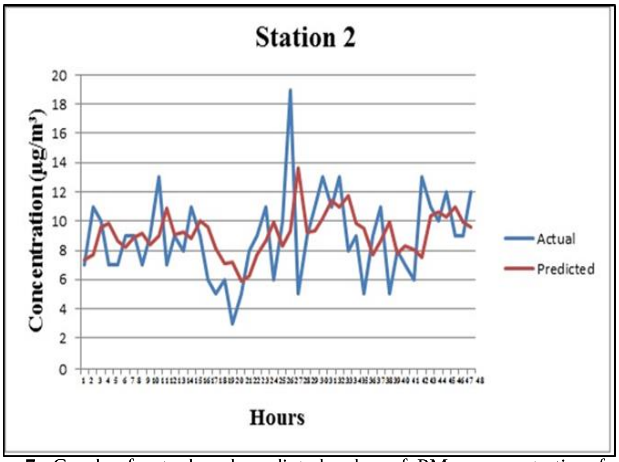

Fig. 7: Graph of actual and predicted value of PM_{10} concentration for Station 2

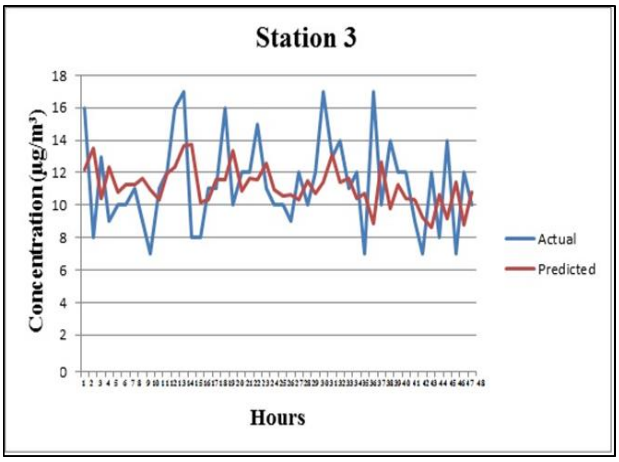

Fig. 8: Graph of actual and predicted value of PM_{10} concentration for Station 3

Since the best model was identified for each station, one model will be selected as the suitable model for Parit Raja Residential Area. The suitable model for Parit Raja was developed by choosing one model from the three stations which was based on the best model from each station. In choosing the suitable model for Parit Raja residential area, the three stations need to fit to each station model such as Station 2 and Station 3 fitted to model AR(1), Station 1 and Station 3 fitted to model ARMA(1,1) and Station 1 and Station 2 fitted to model ARMA(2,1) to get the performance measure in each fitted model. Based on the performance measure, the less different measure value in each fitted model from all stations will be chosen as the best model for Parit Raja. Based on the fitted model in each stations for this project, the best model for Parit Raja is AR(1) where the different value in each stations performance measure is less compared to fitted model ARMA(1,1) and ARMA(2,1). The summarized of performance indicators for fitted model AR(1) is shown in Table 7.

The simple model of AR(1) was fitted as the suitable model for Parit Raja Residential Area based on the smallest error, this model will be used as prediction to get the value of concentration of PM_{10} in hourly average.

Table 7 Equation and result of performance indicator for all monitoring stations

Station	Equation	RMSE	MAE	NAE
Station 1	$y_t = 15.535 - 0.308 y_{t-1} + \varepsilon_t$	5.1898	4.1735	0.3756
Station 2	$y_t = 10.137 - 0.572 y_{t-1} + \varepsilon_t$	3.1368	2.3657	0.2659
Station 3	$y_t = 10.865 - 0.376 y_{t-1} + \varepsilon_t$	3.9687	3.2443	0.2173

6. Conclusion

This study has been found the best time series model for Station 1 located at SMK Tun Ismail is AR(1), Station 2 located at Melewar residential college is ARMA(1,1) and ARMA(2,1) at Station 3 located at SK Pintas Raya. However, for the predicted purpose of PM_{10} concentration for the next 24 hours at any Parit Raja residential area, the most suitable model is AR(1) based on the lowest different value in each performance indicators compared to other time series model. It can be concluded that the aims of this research has been successfully achieved.

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