# Air Pollution Prediction with Hotspot Variable based on Vector Autoregressive Model in Pekanbaru Region

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Abstract: The air quality is widely caused by pollution of particulate matter (PM10) and meteorological elements. For examples, rainfall, solar radiation, air temperature, humidity, wind velocity, and hotspot. In analysis data (ADV), the used variables are more than one variable, so that the best model for modeling and forecasting multivariate data is vector autoregressive (VAR). The VAR model is chosen because it is one of multivariat analysis for time series data and it is able to describe the interconnectedness among variables. The aim of this research is to find the best model for PM10 concentrations with other meteorological elements in Pekanbaru by using VAR model, and to determine the prediction result of PM10 concentration in the future. Furthermore, the monthly data of Pekanbaru region from January 2011 until December 2015 was used for training and testing. The result showed the best model for predicting PM10 is VAR(1). It can be summarized that rainfall, solar radiation, humidity and hotspot variables have been interconnected with PM10. Based on proposed model, the concentration of PM10 data increased from January 2016 until December 2017.



## 1 INTRODUCTION

Air is a very important factor for all substance's life in the earth. It has created by God (Allah SWT) with the sidelines of the wind, as described in the Qur'an Surah Ar-Ruum (48) is *"God is He who sends the winds. They stir up clouds. Then He spreads them in the sky as He wills. And He breaks them apart. Then you see rain drops issuing from their midst. Then, when He makes it fall upon whom He wills of His servants, behold, they rejoice".*

In this decade, the city centers development such as the technological advancements have been raised fast which may influence the air quality negatively. Furthermore, the existence of city center development, the number of plant construction, and the number of new lands opening by companies with burning method will produce the air conditions become dry and dirty. Additionally, the increasing number of motor vehicles also resulted in increased density in traffic so that the quality of the air even more alarming. As explained in the Qur'an Surat Al-A'raf in verse (56) explains about Allah's prohibition to damage the environment to man, because Allah will give a bigger penalty, but man still deny it, as for verse (56) in surah Al-A'raf is *"And do not corrupt on earth after its reformation and pray to Him with fear and hope. God's mercy is close to the doers of good".*

Air pollution is the presence of chemicals in the air which certain characteristics and periods of time whose effects can cause dangerous condition to human body, animal and plant. The prominent substances of air pollution are carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, particulate matter ($PM_{10}$) and the other components. Particulate matter ($PM_{10}$) is microscope which diameter is less than 10 $\mu m$ and it is able to cause a serious effect on human health risks, animal and plant than other larger components, generally it is a result from forest and land burning illegally (Strauss et al, 1984).

In 2015, burning forest and opening land for agriculture had happened in Riau province, so the number of hotspots is very high, it is resulting in high concentration of air pollutant gas such as particulate



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matter (PM10). Therefore, there was air pollution in various regions in Riau Province and even in the areas outside of Riau. In addition to causing illness, fog smoke in Riau, especially in Pekanbaru causes community activities disturbed, such as all education activities in Riau, especially Pekanbaru City have been stopped. One of the universities which halts its academic activities, for 4 days, was the State Islamic University of Sultan Syarif Kasim Riau. Moreover, the visibility on the highway is only ± 200 meters, thus causing rider activity is hampered. Air pollution by particulate matter (PM10) has a dynamic relationship with meteorological elements such as rainfall, solar radiation, air temperature, humidity and wind speed. In addition, the number of hotspots also has a dynamic relationship with air pollution caused by particulate matter (PM10) (Brown and Davis, 1973).

The guidance of Allah SWT about the duty of His people to be grateful for the blessings that Allah Almighty gives which is much explained in the Qur'an, including the favor of the universe that Allah has created for His people. Allah SWT asserted in Qur'an that is for His people who are not grateful for the blessings that Allah Almighty gives, then Allah SWT will give a very painful penalty, which is described in surah Ibrahim verse 7 is "*And when your Lord proclaimed: "If you give thanks, I will grant you increase; but if you are ungrateful, My punishment is severe*".

Several studies related to the study of air pollution modeling and number of hotspots using vector autoregressive (VAR) models have been conducted by, such as a research conducted by Cai (2008) used VAR analysis to predict the time series data of CO pollution in California. Another research is Ahmad, et al (2013) discusses the prediction of air pollution by particulate matter (PM10) using the Box-Jenkins method. Based on the explanation of air pollution, it is necessary to predict the concentration of air pollutant that is especially gas particulate matter (PM10) and relating elements for the future by using vector autoregressive model (VAR). Given the importance of knowing the concentration of particle matter (PM10) in Pekanbaru, this research tries to provide a suitable statistical model for particulate matter (PM10) data in Pekanbaru by using vector autoregressive model (VAR). The purpose of this research is to find the best model for particulate matter density data (PM10) along with meteorological elements in Pekanbaru city by using vector autoregressive model (VAR). And determine the prediction result of particulate matter concentration (PM10) in the future by using vector autoregressive (VAR) model in Pekanbaru city.

# 2 METHODS

## 2.1 Literature Review

Particulate matter (PM10) is particles which diameter is less than 10 μm which can cause more hazardous effect on human health, animal and plant than some other larger particles formed of stationary source such as vehicles (vehicle ekzos). Particulate Matter (PM10) is largely produced from wild forest and land burning. Rainfall is the height of rainwater collected in a flat, non-volatile, non-pervasive and non-flowing place (Chelani et al, 2004).

Solar radiation is energy radiance which comes from thermonuclear process in the sun. Solar energy is the energy source for all of existence. The air temperature is a measure of the average kinetic energy of molecule improvements or the temperature condition of the air. The hotspot is the terminology of a single pixel that has a higher temperature than the surrounding area or location captured by a digital data satellite sensor. Air humidity is the amount of water vapor in the air (atmosphere) at a given time and place. Wind is the air movement parallel to the surface of the earth. Air moves from high pressure areas to low pressure areas (Liew, 2002).

Prediction or forecasting is a forecasting process for the future based on past data. Forecasting is a fundamental thing in determining a plan or policy in an agency this is due to the uncertainty of the values of a variable in the future. Therefore, predictions are very important in many fields because predictions of future events must be incorporated into the process of making a decision. The definition of the VAR model is that all variables present in the VAR model are endogenous. If there is a relationship associate between variables observed, then the variables need to be done the same way. So, there is no longer endogenous and exogenous variables (Bowerman et al, 2005). In general, the model VAR lag p for n variables can be formulated as follows (Makridakis, 1998):

$$Y_t = A_0 + A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + e_t$$

with $Y_t, Y_{t-1}$ is a vector which size is $n \times 1$ containing $n$ variables entered in the VAR model at $t$ time and $t-1$, $i = 1,2,\ldots, p$, $A_0$ is a vector of intercept which size is $n \times 1$, $A_i$ is a coefficient matrix of sizes $n \times n$ for each, , $i = 1,2,\ldots, p$, $e_t$ is a vector of sized $n \times 1$ that is $(e_{1t}, e_{2t}, \cdots, e_{nt})^T$, $p$ is lag VAR, $t$ is a period of observation. The VAR model consisting of two variables and 1 lag is the VAR(1) model:

$$Y_t = \alpha_{10} + \alpha_{11}Y_{t-1} + \alpha_{12}X_{t-1} + e_{1t}$$

$$X_t = \alpha_{20} + \alpha_{21}Y_{t-1} + \alpha_{22}X_{t-1} + e_{2t}$$

According Makridakis et.al (1998), the VAR model advantage is the researchers do not need to distinguish which endogenous and exogenous variables because all variables VAR is endogenous. The method of estimation is simple with the least squares method and can be made in separate model for each endogenous variable. Assumptions that must be met from the times series data to form the VAR model are stationary and independence error (error no autocorrelation).

## 2.2 Data and Research Methodology

The data of air pollution especially particulate matter parameter (PM10) was obtained from the Pekanbaru Environmental station. Meteorological elements such as solar radiation, air temperature, rainfall, humidity and wind speed are obtained from the Meteorology, Climatology and Geophysics (BMKG) station of Pekanbaru, while the data of the number of hotspots (hotspots) obtained from the Center for Natural Resources Conservation Pekanbaru. The data used in this research are the monthly data of air pollution data which parameter particulate matter (PM10), rainfall, solar radiation, air temperature, humidity and wind speed, hotspot number are from 2011 to 2015. The calculation method used in this research is the method of completion based on the formulas of vector autoregressive model (VAR), then applied into the form of EVIEWS and Minitab programming.

## 2.3 Steps in Forming VAR Model

### 2.3.1 Data Stationary Test

A data is said to be stationary if the data has a variance that is not too large and has a tendency to approach the average value (Bierens, 2006). There are many ways that can be used to test the stationary data in time series analysis i.e. see the plot of actual data, see plot ACF and PACF is the actual data plot and plot ACF and PACF is said to stationary if the plot of actual data has average traits and variance which is constant all the time and on ACF plots and PACF plots drop exponentially. Stationary or not stationary data can be tested by running statistical tests i.e. unit root test. There are several statistical tests that can be used to determine the stationary or not stationary. The most commonly used tests are Augmented Dickey Fuller (ADF), Phillips Perron (PP) and Kwiatkowski Phillips Schmidt Shin (KPSS) tests (Bierens, 2006).

### 2.3.2 The Determination of Lag VAR

The lag determination is used to determine the optimal lag length to be used in further analysis and will determine the parameter estimate for the VAR model. According to Bierens (2006) that the VAR lag can be determined using AIC (Akaike Information Criterion), SIC (Schwarz Information Criterion) and HQ (Hannan-Quinn Information Criterion). AIC, SIC and HQ measure the validity of the model that improves the loss of degrees freedom when additional lags are included in the model. Lag VAR is determined by the lag value that results in the smallest AIC, SIC and HQ (Bierens, 2006).

### 2.3.3 Granger Causality Test

The Granger causality test is a test that can be used to analyze the causality relationship between the observed variables. The Granger causality test is used to look at the direction of the relationship between the variables (Vandaele, 1983).

### 2.3.4 The Estimation and Forecasting of VAR

A simple VAR consisting of two variables and 1 lag can be formulated into both equations. The parameters in the VAR model can be estimated by using the maximum likelihood by minimizing the derivative function of the VAR model parameters by minimizing the sum of the error squares for the VAR model equations (Brocklebank & David, 2003).

### 2.3.5 VAR Model Assumption Test

After the VAR model is obtained then the Lagrange Multiplier (LM) is tested by looking at the value of Q-statistics and Chi-square (Chatfield, 2003).

### 2.3.6 The Forecasting for Future Time

The next step in the VAR model is prediction. The VAR model formed from data is used to make predictions that include training and predictions for the future. Training prediction stage, the data used is the first actual until the last actual data. Furthermore, at the prediction stage for the time to come, the data used is the final data from the actual data (Chatfield, 2003).

# 3 RESULTS AND DISCUSSIONS

### The Statistika Descriptive of Data Research

Descriptive statistics for particulate matter concentration (PM10), rainfall, solar radiation, air temperature, humidity, wind speed, and hotspots were observed on a monthly basis for five years, from 2011 to 2015. All data for all variables experience an increasing and decreasing for each month, for the mean, median, maximum value, minimum value and standard deviation can be seen in the following table:

Table 1: Descriptive Statistics PM10, Rainfall, Solar Radiation, Air Temperature, Air Humidity, Wind Speed, and Hotspot.

| Variable | PM10 | Rainfall | Solar Radiation |
|---|---|---|---|
| Mean | 48.43 | 202.8 | 46.40 |
| Median | 27.96 | 184.2 | 50.00 |
| Maximum | 310.31 | 313 | 57 |
| Minimum | 20.38 | 11.1 | 7 |
| Standard Deviation | 9.28 | 123.9 | 14.08 |
| Observasi (N) | 60 | 60 | 60 |
| Variable | Air Temperature | Air Humidity | Wind Speed |
| Mean | 27.135 | 77.467 | 5.5500 |
| Median | 27.200 | 78.000 | 5.8000 |
| Maximum | 27.6 | 80 | 6 |
| Minimum | 25.3 | 69 | 3.7 |
| standard Deviation | 0.646 | 3.762 | 0.6105 |
| Observasi (N) | 60 | 60 | 60 |
| Variable | *Hotspot* | | |
| Mean | 331.0 | | |
| Median | 185.0 | | |
| Maximum | 438.8 | | |
| Minimum | 3 | | |
| standard Deviation | 376.9 | | |
| Observasi (N) | 60 | | |

### The Formation of Prediction Model Particulate Matter 10 (PM10) by using Vector Autoregressive Model (VAR)

An autoregressive vector model (VAR) in formed for the prediction of air pollution data by particulate matter (PM10) and meteorological elements must follow several steps: data validation test, determine optimal lag length of vector autoregressive model (VAR), granger causality test, vector autoregressive model parameters (VAR), test of autoregressive vector model (VAR), and data prediction for the future. Data used in this research are data particulate matter (PM10), rainfall, solar radiation, air temperature, humidity, wind speed (wind speed), and hotspot (hotspot). The data used is time series data from January 2011 to December 2015. Therefore, the amount of data is 60 data.

### Stage 1: The Stationary Data Test

Initial step in processing time series data by using vector autoregressive model (VAR) to predict the time data that will come is a stationary data test. In data processing, we use Minitab and Eviews software. The stationary data test can be analyzed from the plot of actual data, plot autocorrelation function (ACF) and partial autocorrelation function (PACF), and unit root test. In the test phase of the stationary data test can be analyzed from the actual data plot of particulate matter (PM10), rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot with 60 observations from January 2011 to December 2015:

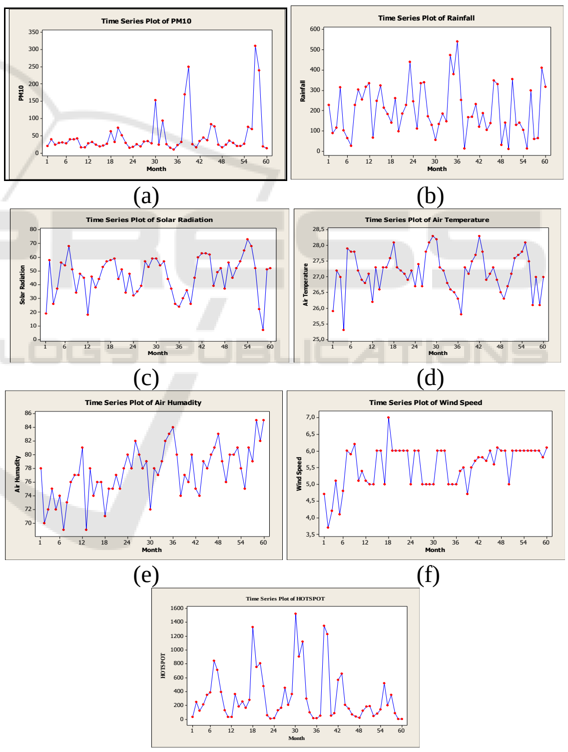



Figure 1: Time series plot for (a) PM10 concentration, (b) rainfall, (c) solar radiation, (d) air temperature, (e) air humidity, (f) wind speed, (g) hotspot in Pekanbaru City.

Based on Figure 1, the graph of particulate matter (PM10), rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot of Pekanbaru shows that all data on all variables meet the requirements of the stationary data test because the data averages and variants move constantly over time.

Data stationary can also be viewed through the plot of autocorrelation function (ACF) and partial autocorrelation function (PACF). Plot ACF and PACF plot can be seen Figure 2 below:

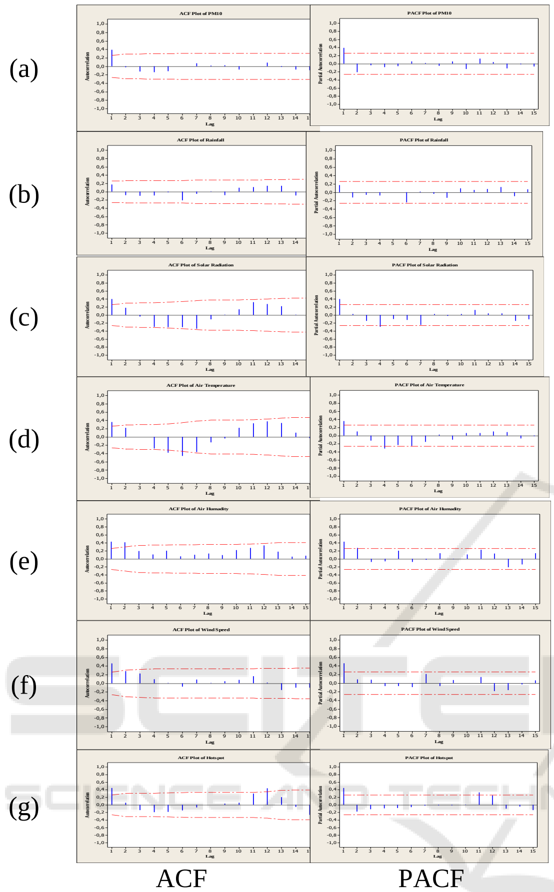



Figure 2: ACF and PACF Plots for (a) PM10 concentration, (b) rainfall, (c) solar radiation, (d) air temperature, (e) air humidity, (f) wind speed, (g) hotspot in Pekanbaru City.

Figure 2 shows that the data particulate matter (PM10), rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot of Pekanbaru have been said to tend to be stationary due to each lag on the ACF plot shrinks towards zero exponentially and PACF shows that its value is truncated to a certain lag. based the two graphs above, the stationary data test can be also through unit root test. The root unit test has been tested using three test types: Augmented Dickey Fuller (ADF), Phillips Perron (PP), and Kwiatkowski Phillips Schmidt Shin (KPSS) tests. The following will be a unit root test for data particulate matter (PM10), rainfall , solar radiation, air temperature, humidity, wind speed (wind speed), and hotspot (hotspot) of Pekanbaru.

Hypothesis testing for ADF test used for data particulate matter (PM10), rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot are $Ho:\delta=0$; that there are root unit (non-stationary data) versus $H1:\delta<0$; that is there is no root unit (stationary data). Hypothesis testing for PP test is $Ho:\delta=0$, there is unit root (data not stationary), the opponent is $H1:\delta<0$, there is no root unit (stationary data). KPSS test has the hypothesis testing $Ho:\delta=0$, there is no root unit (stationary data), and the opponent is $H1:\delta<0$, there is unit root (data not stationary). Test results of PM10 data, rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot using unit root test of ADF, PP and KPSS can be presented in Table 2.

Table 2 shows that all variables have $|t|>$ absolute value for MacKinnon critical value at a significant level of 0.05 or can be seen from the p-value which all p-values in all variables are less than significant 0.05 then decline $Ho$, that PM10 data, rainfall, solar radiation, air temperature, air humidity, wind speed and hotspot do not have root unit, this means that time series for PM10 data, rainfall, radiation sun, air temperature, air humidity, wind speed (wind speed), and hotspot is stationary.

**Stage 2: The Determination of the Optimal Lag Length**

Data particulate matter (PM10), rainfall, solar radiation, air temperature, air humidity, wind speed, and hotspot (fire point) are stationary, the next step is to determine the optimal lag length that will be used in autoregressive vector model (VAR). Based on Eviews software, it is obtained the optimal lag length as in Table 3. In Table 3 can be seen that the values of AIC, SC, and HQ which are asterisks and the smallest among the lags of zero to the third lag are AIC in lag 1. So, we can know that the optimal lag used for the vector autoregressive (VAR) model is on the lag 1 or VAR(1) model.

**Stage 3: The Causality of Granger Test**

After the optimal lag length is obtained, the next step is to test the granger causality. Granger causality test is performed to see whether or not a direct or reciprocal relationship between variables. The following results of granger causality test using Eviews software can be presented in Table 4.

Table 2: ADF, PP, and KPSS Test Value Compared with MacKinnon Critical Values for PM10 Data of Pekanbaru City.

| Variable | ADF | | |
|---|---|---|---|
| | p-value | t-stat | t-critical MacKinnon (5%) |
| PM10 | 0.0001 | -4.96 | -2.912 |
| Rainfall | 0.000 | -6.26 | -2.912 |
| Solar Radiation | 0.0001 | -5.11 | -2.912 |
| Air Temperature | 0.000 | -5.39 | -2.916 |
| Air Humidity | 0.0145 | -3.57 | -2.913 |
| Wind speed | 0.0004 | -4.59 | -2.912 |
| Hotspot | 0.0004 | -4.60 | -2.912 |
| Variable | PP | | |
| | p-value | t-stat | t-critical MacKinnon (5%) |
| PM10 | 0.0004 | -4.64 | -2.912 |
| Rainfall | 0.000 | -6.16 | -2.912 |
| Solar Radiation | 0.0001 | -5.16 | -2.912 |
| Air Temperature | 0.000 | -5.35 | -2.912 |
| Air Humidity | 0.0006 | -4.47 | -2.912 |
| Wind speed | 0.0006 | -4.49 | -2.912 |
| Hotspot | 0.0009 | -4.37 | -2.912 |
| Variable | KPSS | | |
| | t-stat | t-critical MacKinnon (5%) | |
| PM10 | 0.335 | 0.463 | |
| Rainfall | 0.089 | 0.463 | |
| Solar Radiation | 0.077 | 0.463 | |
| Air Temperature | 0.053 | 0.463 | |
| Air Humidity | 0.087 | 0.463 | |
| Wind speed | 0.370 | 0.463 | |
| Hotspot | 0.186 | 0.463 | |

Table 3: The Optimal Lag length.

| *Lag* | AIC | SC | HQ |
|---|---|---|---|
| 0 | 52.75358 | 53.00448* | 52.85109 |
| 1 | 52.05960* | 54.06681 | 52.83967* |
| 2 | 52.22299 | 55.98650 | 53.68562 |
| 3 | 52.35758 | 57.87741 | 54.50278 |

Table 4: The Causality of Granger Test.

| No | Hipotesis | Obs | F-Statistik | *P-Value* |
|---|---|---|---|---|
| 1 | WS not affect RF<br>RF not affect WS | 59 | 0.53571<br>2.03996 | 0.4673<br>0.1588 |
| 2 | AH not affect RF<br>RF not affect AH | 59 | 0.0000063<br>0.00663 | 0.9980<br>0.9354 |
| 3 | PM10 not affect RF<br>RF not affect PM10 | 59 | 0.04065<br>0.23779 | 0.8409<br>0.6277 |
| 4 | SR not affect RF<br>RF not affect SR | 59 | 5.07833<br>1.30892 | 0.0282<br>0.2575 |
| 5 | AT not affect RF<br>RF not affect AT | 59 | 0.12241<br>0.03840 | 0.7277<br>0.8454 |
| 6 | HP not affect RF<br>RF not affect HP | 59 | 0.16547<br>1.26958 | 0.6857<br>0.2647 |
| 7 | AH not affect WS<br>WS not affect AH | 59 | 0.01387<br>6.04835 | 0.9067<br>0.0170 |
| 8 | PM10 not affect WS<br>WS not affect PM10 | 59 | 0.53467<br>0.44312 | 0.4677<br>0.5084 |
| 9 | SR not affect WS<br>WS not affect SR | 59 | 3.37422<br>0.18205 | 0.0715<br>0.6713 |
| 10 | AT not affect WS<br>WS not affect AT | 59 | 5.51941<br>0.31647 | 0.0224<br>0.5760 |
| 11 | HP not affect WS<br>WS not affect HP | 59 | 0.54855<br>0.88732 | 0.4620<br>0.3503 |
| 12 | WS not affect RF<br>RF not affect WS | 59 | 0.53571<br>2.03996 | 0.4673<br>0.1588 |
| 13 | AH not affect RF<br>RF not affect AH | 59 | 0.0000063<br>0.00663 | 0.9980<br>0.9354 |
| 14 | PM10 not affect RF<br>RF not affect PM10 | 59 | 0.04065<br>0.23779 | 0.8409<br>0.6277 |
| 15 | SR not affect RF<br>RF not affect SR | 59 | 5.07833<br>1.30892 | 0.0282<br>0.2575 |
| 16 | AT not affect RF<br>RF not affect AT | 59 | 0.12241<br>0.03840 | 0.7277<br>0.8454 |
| 17 | HP not affect RF<br>RF not affect HP | 59 | 0.16547<br>1.26958 | 0.6857<br>0.2647 |
| 18 | AH not affect WS<br>WS not affect AH | 59 | 0.01387<br>6.04835 | 0.9067<br>0.0170 |
| 19 | PM10 not affect WS<br>WS not affect PM10 | 59 | 0.53467<br>0.44312 | 0.4677<br>0.5084 |
| 20 | SR not affect WS<br>WS not affect SR | 59 | 3.37422<br>0.18205 | 0.0715<br>0.6713 |
| 21 | AT not affect WS<br>WS not affect AT | 59 | 5.51941<br>0.31647 | 0.0224<br>0.5760 |
| 22 | HP not affect WS<br>WS not affect HP | 59 | 0.54855<br>0.88732 | 0.4620<br>0.3503 |

where PM10 is particulate matter 10, RF is rainfall, SR is solar radiation, AT is air temperatur, AH is air humidity, WS is wind speed, and HP is hotspot.

Base on table 4, it is obtained the result of Granger's causality test as:

- Granger's causality test, wind speed and rainfall :

a. $H_0$: wind speed doesn't affect rainfall
$H_1$: wind speed affects rainfall
Rejection area: if p-value < $\alpha$ then $H_0$ is rejected, otherwise if P-value $\geq \alpha$ then $H_0$ is accepted. Based on the test results obtained that the P-value $\geq \alpha$ is $0.4673 \geq 0.05$. This means that $H_0$ is

accepted so that wind speed does not affect rainfall.

b. $H_0$: Rainfall doesn't affect wind speed
$H_1$: Rainfall affects wind speed
Rejection area: if P-value $<\alpha$ then $H_0$ is rejected, otherwise if P-value $\geq \alpha$ then $H_0$ is accepted. Based on the test results obtained that the P-value $\geq \alpha$ is $0.1588 \geq 0.05$. This means that $H_0$ is accepted so that rainfall does not wind speed.

For Granger Causality testing no. 2-21 may be carried out in the same manner in the test above. Based on the Granger Causality test before, it can be seen that who has causality between variables i.e. solar radiation affects rainfall, wind velocity affects air humidity, air temperature affects wind speed, PM10 affects the amount of hotspot and solar radiation affects air temperature. So, it can be concluded that the elements of rainfall, solar radiation, air temperature, and hotspots have a relationship to PM10.

**Stage 4: Parameter Estimation**

This step is a parameter estimating step for the VAR model. In the second step, it has obtained the length of the lag is 1 which consists of 7 variables so that the resulting model to be estimated is VAR(1). The VAR(1) model can be :

$$PM_t = \alpha_{10} + \alpha_{11}PM_{t-1} + \alpha_{12}RF_{t-1} + \alpha_{13}SR_{t-1} + \alpha_{14}AT_{t-1} + \alpha_{15}AH_{t-1} + \alpha_{16}WS_{t-1} + \alpha_{17}HP_{t-1} \quad (1)$$

$$RF_t = \alpha_{20} + \alpha_{21}PM_{t-1} + \alpha_{22}RF_{t-1} + \alpha_{23}SR_{t-1} + \alpha_{24}AT_{t-1} + \alpha_{25}AH_{t-1} + \alpha_{26}WS_{t-1} + \alpha_{27}HP_{t-1} \quad (2)$$

$$SR_t = \alpha_{30} + \alpha_{31}PM_{t-1} + \alpha_{32}RF_{t-1} + \alpha_{33}SR_{t-1} + \alpha_{34}AT_{t-1} + \alpha_{35}AH_{t-1} + \alpha_{36}WS_{t-1} + \alpha_{37}HP_{t-1} \quad (3)$$

$$AT_t = \alpha_{40} + \alpha_{41}PM_{t-1} + \alpha_{42}RF_{t-1} + \alpha_{43}SR_{t-1} + \alpha_{44}AT_{t-1} + \alpha_{45}AH_{t-1} + \alpha_{46}WS_{t-1} + \alpha_{47}HP_{t-1} \quad (4)$$

$$AH_t = \alpha_{50} + \alpha_{51}PM_{t-1} + \alpha_{52}RF_{t-1} + \alpha_{53}SR_{t-1} + \alpha_{54}AT_{t-1} + \alpha_{55}AH_{t-1} + \alpha_{56}WS_{t-1} + \alpha_{57}HP_{t-1} \quad (5)$$

$$WS_t = \alpha_{60} + \alpha_{61}PM_{t-1} + \alpha_{62}RF_{t-1} + \alpha_{63}SR_{t-1} + \alpha_{64}AT_{t-1} + \alpha_{65}AH_{t-1} + \alpha_{66}WS_{t-1} + \alpha_{67}HP_{t-1} \quad (6)$$

$$HP_t = \alpha_{70} + \alpha_{71}PM_{t-1} + \alpha_{72}RF_{t-1} + \alpha_{73}SR_{t-1} + \alpha_{74}AT_{t-1} + \alpha_{75}AH_{t-1} + \alpha_{76}WS_{t-1} + \alpha_{77}HP_{t-1} \quad (7)$$

The result of parameter estimation is obtained using Eviews software. The results of the VAR(1) model parameter estimation are presented in equations below. The model parameters can be substituted into the VAR(1) model using equations (1), (2), (3), (4), (5), (6), and (7):

$$PM_t = 149.738 + 0.4162PM_{t-1} - 0.0524RF_{t-1} + 0.9364SR_{t-1} - 12.9010AT_{t-1} + 2.4060AH_{t-1} + 1.5020WS_{t-1} + 0.0048HP_{t-1} \quad (8)$$

$$RF_t = -995.588 - 0.4290PM_{t-1} + 0.1336RF_{t-1} - 5.8629SR_{t-1} + 60.1550AT_{t-1} - 5.8621AH_{t-1} + 52.4149WS_{t-1} - 0.0175HP_{t-1}. \quad (9)$$

$$SR_t = -197.372 - 0.0975PM_{t-1} - 0.0367RF_{t-1} + 0.0553SR_{t-1} + 6.1958AT_{t-1} + 0.9911AH_{t-1} + 1.3836WS_{t-1} + 0.0040HP_{t-1} \quad (10)$$

$$AT_t = 22.301 + 0.0004PM_{t-1} - 0.0003RF_{t-1} + 0.0206SR_{t-1} + 0.1089AT_{t-1} + 0.0254AH_{t-1} - 0.1762WS_{t-1} + 0.0000067HP_{t-1} \quad (11)$$

$$AH_t = 33.1204 + 0.0265PM_{t-1} + 0.0058RF_{t-1} + 0.02105SR_{t-1} + 0.501AT_{t-1} + 0.2323AH_{t-1} + 1.8505WS_{t-1} - 0.00276HP_{t-1} \quad (12)$$

$$WS_t = -3.85 + 0.0015PM_{t-1} - 0.00044RF_{t-1} + 0.0085SR_{t-1} + 0.1772AT_{t-1} + 0.0282AH_{t-1} + 0.372WS_{t-1} - 0.0000758HP_{t-1} \quad (13)$$

$$HP_t = -2144.33 - 2.565PM_{t-1} - 0.877RF_{t-1} - 0.4899SR_{t-1} + 35.0203AT_{t-1} + 28.342AH_{t-1} - 101.849WS_{t-1} + 0.6747HP_{t-1}. \quad (14)$$

**Stage 5: Verification of VAR Model**

When the model for prediction is obtained, VAR(1), it needs to verification by using test Lagrange Multiplier Test (LM test). This verification is done by checking whether the residual correlated or not by using Lagrange Multiplier test (LM test), this test is using Eviews software. The hypothesis testing of the Lagrange Multiplier test is $H_0$: There is no significant autocorrelation to the h-lag (feasible model) versus H1: There is significant autocorrelation to the h-lag (improper model). By using a significant level, it can be determined a criterion which is if the p-value > $\alpha$ , $H_0$ is accepted which means there is no significant autocorrelation component until lag *h* or feasible model. Vice versa if the p-value $\leq \alpha$ then $H_0$ is rejected, which means there is a significant autocorrelation component until the h lag or model is not feasible. Table 5 is the result of Lagrange Multiplier test.

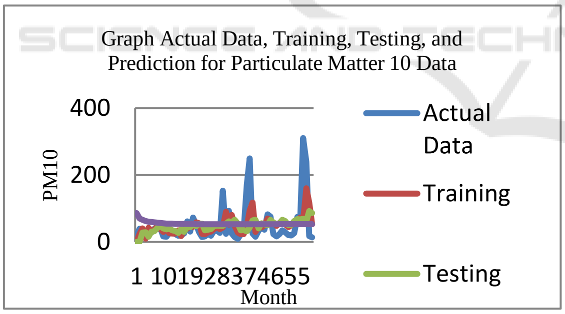
Based on Table 5 above, it is found that all p-values exceed the significant or p-value $> \alpha$ for all lags or up to twelve lags. This means that there is no significance component at 5% alpha, all $p$-values in each lag greater than 0.05 indicate that no autocorrelation or model error exists.

Table 5: The Result of Lagrange Multiplier Test (LM Test).

| *Lags* | LM-Stat | Prob | *Lags* | LM-Stat | Prob |
|---|---|---|---|---|---|
| 1 | 65.00721 | 0.0625 | 7 | 46.15437 | 0.5892 |
| 2 | 56.12147 | 0.2255 | 8 | 50.94637 | 0.3969 |
| 3 | 62.02264 | 0.1002 | 9 | 43.65337 | 0.6890 |
| 4 | 50.83375 | 0.4012 | 10 | 31.50254 | 0.9754 |
| 5 | 50.50584 | 0.4138 | 11 | 57.62338 | 0.1864 |
| 6 | 41.54211 | 0.7664 | 12 | 55.25166 | 0.2504 |

**Stage 7: Application of Models for Forecasting**

After running the goodness model test using the LM test, which states that the VAR(1) model is feasible to be used for prediction in the future and after performing prediction for data training and data testing, further predictions are made for future time on particulate matter (PM10) and hotspots. Prediction of particulate matter concentration (PM10) and hotspot data begins from January 2016 to December 2017. The prediction result of particulate matter (PM10) and hotspot can be presented in the following graph:



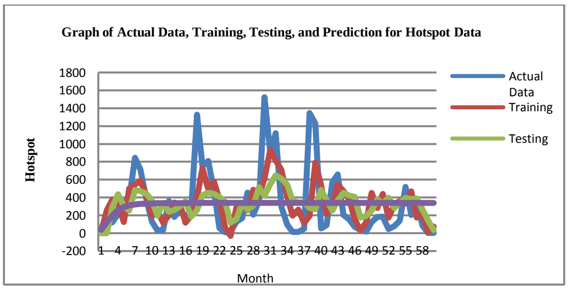




Figure 3: Graph of Actual Data, Training, Testing, and Prediction Data for PM10 (above) and Hotspot Data (below) from January 2016 to December 2017.

Based on Figure 3 we can see that the prediction results of particulate matter (PM10) of Pekanbaru from January 2016 to December 2017 experienced a slight decreased from the previous month in 2016 until 2017. As for the prediction of Riau's hotspot data (hotspots) from January 2016 to December 2017 experienced a slight increase from the previous months.

## 4 CONCLUSIONS

In this paper, we obtained the prediction model for particulate matter (PM10) with some external variable (vector), namely, the rainfall, the solar radiation, the air temperature, the air humidity, the wind speed and the hotspot. Mathematically has been explained in the Equation (15). By using this equation (model), the prediction of air pollution (data training) can be achieved closely with their actual data. Additionally, these also occurred with prediction of the meteorological particles. While, the data testing is not fully achieved using proposed model for both data sets. Thus, the prediction of PM10 has been decreased from January 2016 until December 2017 at Pekanbaru region. On the other hands, the hotspot prediction was almost same with their actual data from the same period. From Granger test, some external vector above also contributed potentially to PM10.

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