Analysis PM10 and Visibility During Forest Fire in Palangka Raya

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Abstract. Forest fires have an impact on air quality and visibility. Visibility can be associated with a highly visual indicator of air pollution. This research aims to analyze the relationship between the PM10 concentration and visibility during the forest fire events and normal conditions in Palangkaraya from 2000 to 2014 by using a regression method. The relative humidity data was used to filter the PM10 and visibility. Furthermore, the equation resulted from the regression analysis was used to predict PM10 concentration in Palangka Raya. The result showed that the regression pattern tends to form a logarithmic function. Specifically, without filtering data, the coefficient correlation (r-value) during the forest fire events and normal conditions are 0.69 and 0.5, respectively. Meanwhile, a data filtering method gives a higher relationship between PM10 and visibility, with the r-value of 0.7 for the forest fire events and 0.68 for the normal condition. On the other hand, the prediction of PM10 concentration indicates a high bias value due to the other influenced factors that have not been included in this study.

1. Introduction

Forest fires often hit Indonesia, especially in Kalimantan and Sumatra [1]. Forest fires emit large amounts of gases and particulates into the atmosphere. Forest fires have an important role in atmospheric chemistry and contribute to climate change [2]. Particulates are dangerous pollutants when forest fires occur, which are usually in the form of haze [3]. Forest fires that occurred in 2002 in Palangka Raya emitting large amounts of PM10 concentrations, around 50x10^{-6} g/m3 in early August, and reaching their highest values in October around 1905 x 10^{-6} g/m3, this is hazardous for human health [4].

The increasing of particulates concentration in the atmosphere has an impact on reducing atmospheric visibility. Visibility usually refers to a particular direction where the object could be visually seen without assistance [5]. Based on previous research in Sumaryati et al. 2019, a high concentration of PM10 will significantly reduce visibility, where visibility in normal condition or no forest fire, the range’s value between 6.4 km – 7.7 km, but when there is a large forest fire, the visibility can drop until 0.1 km.

Atmospheric visibility is usually strongly influenced by the number of pollutants in the atmosphere. Therefore, visibility is used as a visual indicator and is relevant to the level of air pollution [7]. Several studies have used visibility as an indicator in seeing the level of air pollution [8,9,10]. Another study also revealed that atmospheric visibility could be associated with health effects, such as increased...
respiratory and cardiovascular disease associated with decreased visibility in Shanghai, China, where a decrease in the distance in the 8 km interquartile range correlates with increased mortality 3.02% [11]. This study continued previous research by focusing on regression analysis between PM10 concentrations and visibility in the Palangka Raya. The equation from regression analysis to predict PM10 concentration in Palangka Raya. This research is expected to be helpful to assist in monitoring particulate concentrations, especially PM10 when forest fire occurs because the availability of particulate monitoring data limited.

2. Data and Method
The data used are PM10 concentration data, visibility, and humidity data in Palangka Raya City from 2000 – 2014. PM10 concentration data were obtained from PM10 monitoring conducted by the Environmental Agency of Palangka Raya City using the Air Quality Monitoring System (AQMS) in Tjilik Riwut Airport, Palangka Raya, while data on visibility and humidity were downloaded from the Ogimet website, https://www.ogimet.com/gsynres.phtml.en.

Data processing was carried out using simple linear regression analysis between PM10 concentration and visibility during forest fires and normal conditions. Regression analysis was performed using excel. The general equation for simple linear regression used is [12]:

\[ Y = a + bX \]

Where: 
- \( Y \) = Dependent variable
- \( X \) = Independent variable
- \( a \) = constant (intersep)
- \( b \) = slope

\[ a = \frac{(\Sigma Y)(\Sigma x_i^2) - (\Sigma x_i)(\Sigma x_i y_i)}{n\Sigma x_i^2 - (\Sigma x_i)^2} \]  

\[ b = \frac{n\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{n\Sigma x_i^2 - (\Sigma x_i)^2} \]

\[ r = \sqrt\frac{n\Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)}{\sqrt{[(n\Sigma x_i^2 - (\Sigma x_i)^2)][n\Sigma y_i^2 - (\Sigma y_i)^2]}} \]  

Furthermore, data filtering was carried out by eliminating PM10 and visibility when the relative humidity value was <76.5% [9]. The equation resulted from the regression analysis was used to predict PM10 concentration in Palangka Raya. Bias calculation was carried out to see how much deviation the predicted PM10 concentration is from the observed PM10 concentration. The calculating of the bias is:

\[ \% \text{ Bias} = \left( \frac{PM10_{\text{obs}} - PM10_{\text{pred}}}{PM10_{\text{obs}}} \right) x 100\% \]  

3. Result and Discuss
3.1 PM10 and Visibility
Palangka Raya is one of the areas in Kalimantan that is prone to forest fires [13, 1, 6]. From figure 1, the highest PM10 concentration reached 1904.75 µg/m³ in 2002, and the lowest concentration was because in 2002 there was a large forest fire in Palangka Raya [13]. This condition is hazardous for human health because it is above the Indonesian national air quality value is 150 µg / m³ [14]. The effect on human health could be increasing the sensitivity in patients with asthma and bronchitis [1]. The hazardous condition lasts for 80 days, followed by an increase in SO₂, NO₂, CO, and O₃ [4]. The peak concentration of PM10 is seen during forest fires, which is accompanied by a decrease in visibility.
Based on figure 1, the increase in PM10 concentration during forest fires was followed by decreasing visibility. There is an inverse peak between the PM10 and visibility. In general, the decreasing visibility during forest fires is a serious problem, because it is closely related to the level of pollution at the time of forest fires.

The monthly pattern of PM10 and visibility in Palangka Raya, presented in Figure 2, showed the increase of PM10 concentration between August and October, but the visibility decrease during the same period. An increase in PM10 concentration and decrease in visibility from August to October can be expected due to forest fires in Palangka Raya which often occur at the end of the dry season [6,15].

Based on the box plot, the different changes in August - October followed by large distribution of PM10 concentration. The large distribution of PM10 concentration is due to the difference of forest fires areas each year which is influenced by global weather phenomena, especially El Nino, in addition to economic factors. As a result, the distribution of visibility values is also large during this period [16].
In this research, the regression analysis between PM10 and visibility is divided into two conditions, forest fire condition, and normal conditions. The forest fire condition used PM10 concentration above 150 µg/m³, while for normal conditions used PM10 concentrations below 150 µg/m³. Based on Figure 3, it can be seen that the PM10 concentration and visibility have a non-linear regression relationship which is a negative relationship during forest fires and normal conditions, the increasing of PM10 concentration, and decreasing of visibility value. The regression of forest fire condition was in the form of exponential regression, with a coefficient of determination $r^2 = 0.47$. Meanwhile, during normal conditions, the regression is logarithmic with a determination coefficient of $r^2 = 0.24$. This explains that the PM10 concentration affects visibility by 47% during forest fires and 24% during normal conditions. Meanwhile, the remaining 53% during forest fires and 76% in normal conditions are influenced by other factors.

![Figure 3. Regression analysis between PM10 and visibility in forest fire and normal conditions.](image)

Based on previous research conducted by Sumaryati et al, 2019, the regression analysis between PM10 and visibility needs to consider for PM10 concentrations above 50 µg/m³, because for PM10 concentrations below 50 µg/m³, many influencing factors such as meteorological factors and other pollutants significantly influence visibility reduction. The Low value of the coefficient of determination during normal conditions, presumably because in these conditions the PM10 concentration is mostly below 50 µg/m³.

3.2 Meteorological Factor

Meteorological factors are a key factor in explaining the relationship between PM10 and visibility [8]. Figure 4 shows that during forest fires in 2002, the increase in PM10 concentration was followed by a decrease in visibility, humidity, and temperature. Precipitation in 2002 was seen to be lower when compared to all years in 2000 until 2014. Wind speeds also showed low wind speeds at the peak of the forest fires in 2002, this led to an accumulation of PM10 and worsened visibility.

Based on research that has been done, the relationship between PM10 and visibility (24 hours) is influenced by humidity and wind direction [9,17,18]. PM10 concentration will decrease with increasing humidity [9], most aerosols such as ammonium sulfate and ammonium nitrate are hygroscopic, where the particulate size will increase with increasing humidity. The size of aerosol growth is also associated with a non-linear increase in light scattering capability, which affects the reduction in visibility [19]. Low wind speed combined with temperature inversion indicates stable conditions as a result of a limited dispersion of pollutants causing high concentrations of PM10 and low visibility [17].
Precipitation influences the process of removing particulates in the atmosphere, high precipitation will have the chance to clean up particulates in the atmosphere more than low precipitation. Many factors have influenced the removal of particulates in the atmosphere, such as the intensity of precipitation, raindrop diameter, and also the diameter of the particulate. The process of removing particulates by precipitation has high uncertainty [20]. The precipitation process can also increase or decrease visibility, but there is no significant correlation between changes in visibility and precipitation [21].

Furthermore, to improve the determination coefficient, the relative humidity data was used to filter the PM10 and visibility. PM10 data and visibility when relative humidity > 76.5% is deleted. Based on Figure 5, it can be seen that the coefficient of determination increases to 54% for forest fires condition with the non-linear regression function being a logarithmic function. Meanwhile, for normal conditions, the coefficient of determination is 45%. Based on this condition, it can be seen that humidity influences the regression analysis between the PM10 concentration and visibility for the Palangka Raya at forest fires and normal conditions.
3.3 PM10 Prediction using Visibility

When a forest fire occurs, a large amount of smoke and dust will be emitted into the atmosphere. This smoke consists of particulates of various sizes which are very dangerous to human health [1]. This smoke causes thick fog that can affect visibility, which indicates poor air quality [10]. PM10 concentrations data are needed when forest fires occur. Because the PM10 data is a reference for anticipatory steps that can be taken by the government, especially for severe fires whose smoke haze can impact not only the location of forest fires but also the surrounding areas and neighboring countries.

Based on the regression analysis between the concentration of PM10 and visibility, a prediction of the concentration of PM10 was carried out using the visibility data. Prediction calculation is done by recalculating the PM10 concentration using the regression equation $y = -249\ln(x) + 595.81$ for forest fire conditions, and $y = -80.92\ln(x) + 204.01$ for normal conditions. From recalculating the observed PM10 concentration using the regression equation for each condition, the mean, standard deviation, minimum and maximum values were obtained as examined in Table 1.

| Tabel 1. Descriptive statistic of measured and predicted PM10 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Forest Fire     | PM10 obs        | PM10 predic     | Normal          | PM10 obs        | PM10 predic     |
| Mean            | 446.42          | 480.32          | Mean            | 39.45           | 39.15           |
| SD              | 318.64          | 233.18          | SD              | 32.14           | 21.58           |
| Max             | 1778            | 1169            | Max             | 150             | 143             |
| Min             | 150             | 57              | Min             | 6.86            | 4.98            |

Based on the descriptive analysis presented in Table 1, it can be seen that the standard deviation value which is quite high during forest fires shows a wider data distribution compared to normal conditions. It can be seen that the average observed and predicted PM10 values do not show a significant difference. However, the minimum value in PM10 the prediction of forest fires has a significant difference. Based on figure 6, it can be seen that the predictive PM10 concentration pattern follows the concentration pattern of the observed PM10. However, some appear to be underestimating or overestimating the observed PM10 concentration, so that a fairly large bias value is obtained.
Figure 6. Regression analysis between PM10 and visibility for forest fire conditions (A) and normal conditions (B) by filtering data RH < 76.5%.

4. Conclusion
Regression analysis of PM10 and visibility for forest fire conditions and normal conditions shows a nonlinear regression relationship with a logarithmic function. Relative humidity has a role in the regression analysis between PM10 and visibility. The PM10 prediction value from the regression equation obtained still has a large bias value, this is presumably because it has not included other meteorological factors in the regression equation.

Acknowledgement
This research was funded by The Center for Atmospheric Research and Technology, The National Institute of Aeronautics and Space. Thank you to the head of Palangka Raya Environmental Agency for supporting PM10 data and Ogimet for supporting visibility data.

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