International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 4 | Issue: 6 | Nov – Dec 2023 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v4i6.15

Investigation of Rainfall Influence on Characteristics of Particulate Matter 2.5 in Jakarta City

Shafiya Qonita Ramadhina

Environmental and Civil Engineering, Institute of Technology Bandung
Ganesha street No 1, Bandung, Indonesia

*Corresponding author details: Shafiya Qonita Ramadhina; Shafiyaqonii@gmail.com

ABSTRACT

This study aims to investigate the impact of rainfall on the characteristics of particulate matter 2.5 in Jakarta city. The particulate matter 2.5 has an adverse impact on human life, while the precipitation reduces concentrations of pollutants in the environment, thus the scavenging effect of PM2.5 by precipitating must be investigated. It needs secondary data of PM 2.5 taken from the AirNow Department of State, meanwhile rainfall data has been extracted from the Meteorological, Climatological, and Geophysical Agency (BMKG). Some analyses have been conducted to understand the influence of rainfall impact on PM 2.5 presence in the atmosphere above Jakarta city. The windrose analysis is performed to know the amount of pollutants transported in one location. Then, the fluctuations in rainfall juxtaposing with the average PM 2.5 concentration to see PM 2.5 concentration while rainfall exists. Subsequently, the data correlations are analyzed using a correlation test based on the Spearman correlation method. As a result, the scarcity of rainfall results in elevated concentrations of PM 2.5, and most likely when higher rainfall, the lower PM 2.5 concentration. Moreover, there is a significant correlation between precipitation levels and PM 2.5 concentrations, as evidenced by the 2019 data, which exhibits an R-value of -0.52.

Keywords: rainfall; PM 2.5; Spearman correlation; windrose; Jakarta city

INTRODUCTION

PM2.5 has been identified as a major source of air pollution in major cities throughout Southeast and South Asia [1]. Organization World Health (WHO) has set PM2.5 exposure concentration limits (fine particles with a diameter of less than 2.5 μm) annual average of 5 μg/m3, but only about 5% of the world's population lives in areas with PM2.5 concentrations meet these limits [2]. PM2.5 can enter the human lungs and the cardiovascular system, thereby increasing morbidity and mortality in cardiopulmonary [3,4]. A number of epidemiological studies have found that PM2.5 exposure has a significant impact on diabetes mellitus [5]. Recent studies have also found that even low levels of PM2.5 can have a negative impact on public health [6].

Rainfall is a meteorological factor that can influence the presence of pollutants in the air. Rain itself causes a scavenging effect that will clean the particles from the atmosphere and will increase visibility and dissolve gas and particulate pollutants which results in generally better air quality [7]. This has the potential to reduce PM 2.5 concentration.

Increasing the impact of PM 2.5 may be dangerous for human life in a regional city on both health and the environment.

Therefore, the research focusing on the impact of rainfall on the presence of PM 2.5 in the atmosphere needs to be addressed to see how effective the scavenging by rainfall on PM 2.5 is in Jakarta city.

RESEARCH METHODOLOGY

In this research, Jakarta city, the capital city of Indonesia, was selected as a study case due to its social significance. The secondary data is used in the form of data on the concentration of PM 2.5 taken from the air quality monitoring station (AQMS) in the AirNow US embassy in Jakarta. The data was stored for every daily hour in years since 2016-2019.

The processing data starts with raw data that may contain errors that need to be cleaned by erasing invalid data. Then, the processing data continues with the calculation of compound data capture of PM 2.5 and rainfall to determine the level of data representation. The determination of the minimum limit of data availability is based on provisions from the Ministry of Environment and Forestry, namely the operation of the Air Quality Monitoring System (AQMS). It is considered valid when the available AQMS monitoring data is at least 75% of all monitoring data from daily measurements.

However, the captured data is still less. than 75% may be less representative, but it is only used as an overview of the patterns of PM 2.5 fluctuation.

The processing was continued by conducting the windrose analysis to see the presence of pollutant transport from various areas. Then, the descriptive statistical analysis was carried out using the line graph for juxtaposing PM 2.5 and rainfall data. It is visually carried out by plotting the average trends per hour of PM 2.5 concentrations in a dasarian period and the amount of rainfall in a dasarian period in 2016-2019. Dasarian is a meteorological term stated as a unit of time with a period of ten days. According to the meteorology and geology agency, the dasarian use for determining wet and dry seasons is as follows: [8].

1) The beginning of the dry season is determined based on the amount of rainfall in one season (10 days) of less than 50 millimeters and followed by several subsequent periods.

2) The beginning of the wet season is determined based on the amount of rainfall in one season (10 days) equal to or more than 50 millimeters and followed by several subsequent periods.

The basis of measurement is ten days time span which is one month divided into 3 (three) periods, namely dasarian I from the 1st to the 10th, dasarian II from the 11th to the 20th, and dasarian III from the 21st to the end of the month.

Lastly, the correlation analysis was also carried out with the correlation test using SPSS software preceding a normal data test. In addition, data transformation is also carried out to determine if the method used abnormal data. Based on testing, the raw data, and the results of the transformation it still uses abnormal data. To overcome the abnormal data condition, the correlation test based on the Spearman correlation method is used. The Correlation analysis was performed on PM 2.5 compounds with rainfall. In supporting the correlation analysis between compounds, R-studio is used to determine the correlation coefficient and the significance of the relationship. This is done to see the interaction relationship between PM 2.5 compounds with rainfall.

DATA ANALYSIS

• Windrose Analysis

It is important to analyze the dominant wind directions to know the particulate matter 2.5 transport behaviour. PM 2.5 has long-range transport behavior yet long-lived in the atmosphere. For instance, long-term monitoring studies on islands such as Oki Island, Japan [9], and Jeju Island, Korea [10,11], have characterized the aerosols transported from the other Asian continent [12].

The data on wind speed is downloaded from the Meteorological, Climatological, and Geophysical Agency (BMKG) in the Jakarta region precisely at Kemayoran Meteorological Station.

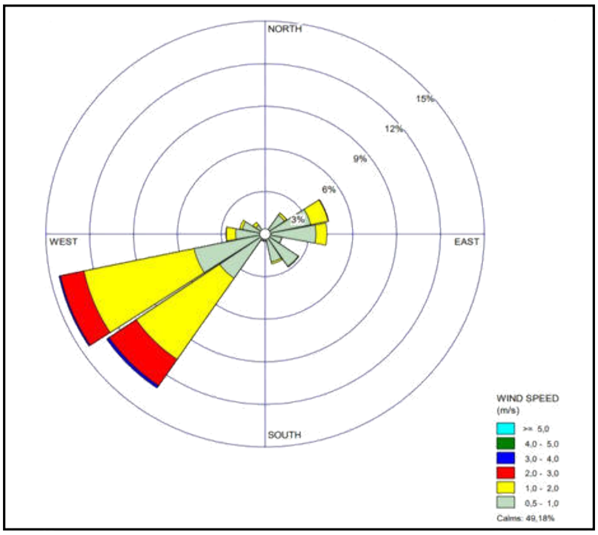

FIGURE 1: Windrose in Jakarta.

The dominant wind direction comes from the West- Southwest side. Even though it is dominant, the wind speed at the central Jakarta location is not too great. It can be seen that the percentage of wind speed from this direction in the range of 2-3 m/s and 3-4 m/s is only 4.5% and 0.3%, while the highest wind speed is in the range of 1-2 m/s, which is around 18.1%. The percentage of calm wind at this location is quite large, reaching 49.2%.

This means that pollutant concentrations are likely to be dominated by local sources. However, if considering the direction of the wind, pollutants PM 2.5 can be carried from other locations, such as Jalan S.Parman which is on the southwest side of the US embassy.

• Analysis Rainfall and PM 2.5

Analysis of rainfall patterns on PM 2.5 will be carried out by looking at the amount of rainfall fluctuation for each period. The green box will show a low concentration of PM 2.5 and the red box will show a high concentration of PM 2.5.

Figure 2 shows the maximum PM 2.5 concentration was around 60-70 ug/m3 and the minimum was around 20-25 ug/m3. Moreover, some dasarian periods show rainfall in May until December is pretty low with the minimum value below 20 mm. It is also followed by a higher concentration of PM 2.5 compared to the concentration of PM 2.5 in February while the rainfall is so high.

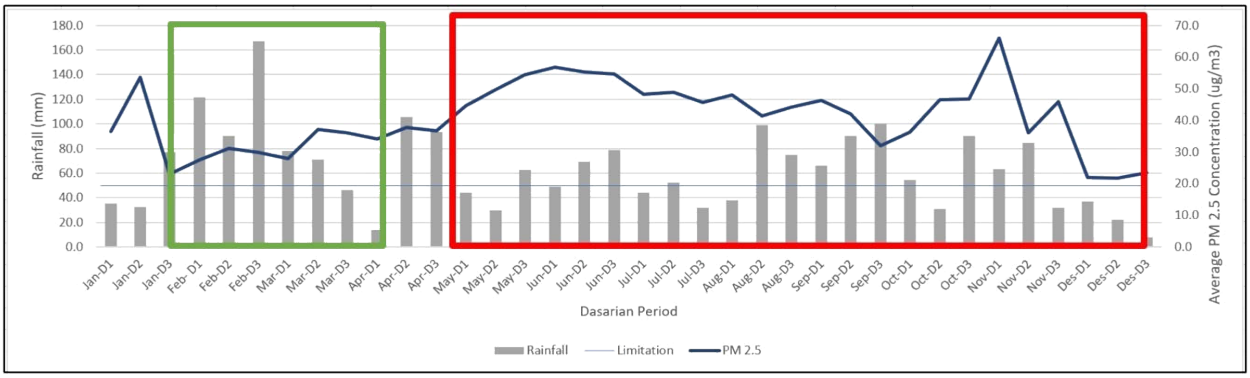

FIGURE 2: Fluctuations of PM 2.5 Concentration on Total Rainfall in 2016.

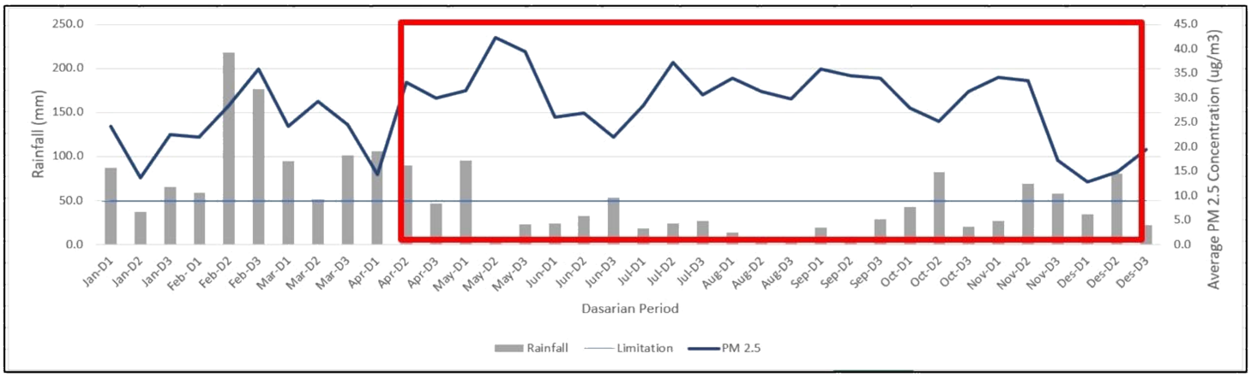

FIGURE 3: Fluctuations of PM 2.5 Concentration on Total Rainfall in 2017.

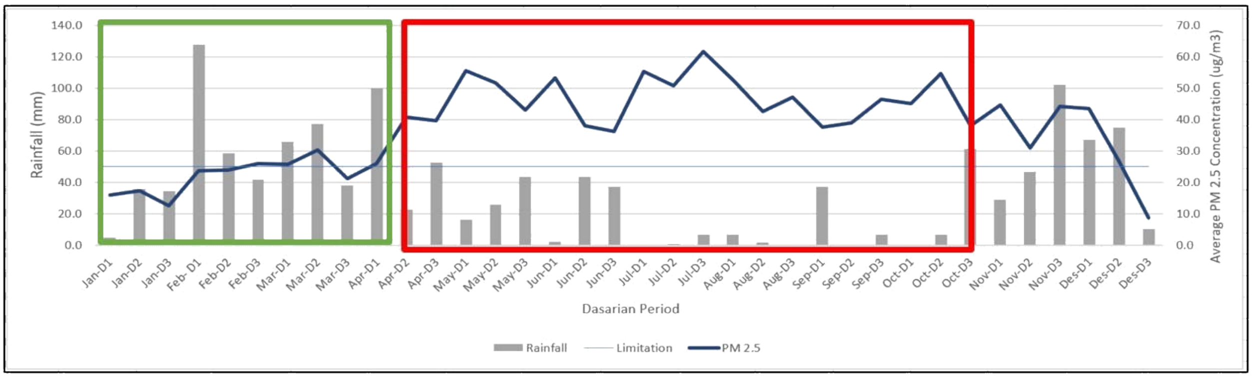

FIGURE 4: Fluctuations of PM 2.5 Concentration on Total Rainfall in 2018.

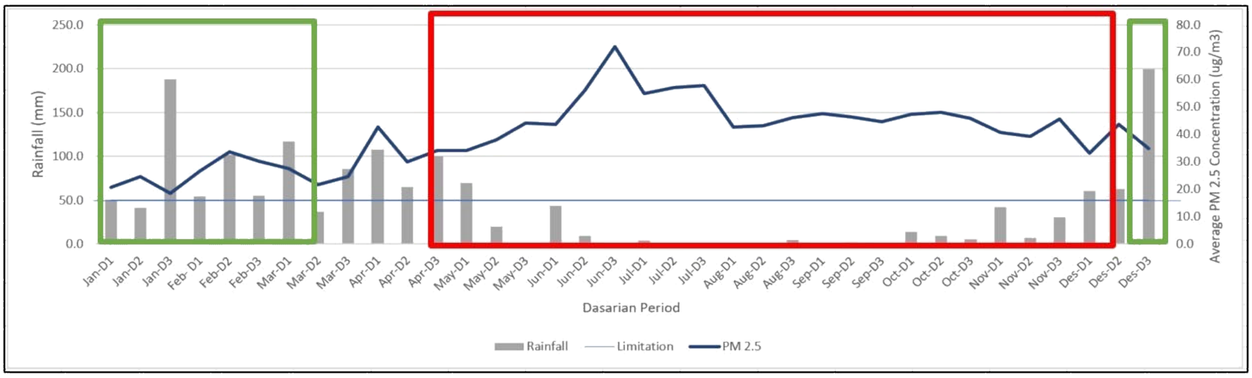

FIGURE 5: Fluctuations of PM 2.5 Concentration on Total Rainfall in 2019.

Figure 3 shows the maximum PM 2.5 concentration is around 40-45 ug/m3. From the middle of April until December there was pretty low rainfall with a minimum value below 50 mm. Higher concentration of PM 2.5 also happens in that range of time. However, there is an abnormal situation which shows a high concentration of PM 2.5 in February while the rainfall is at the highest level.

Figure 4 shows the maximum PM 2.5 concentration is around 60-70 ug/m3. In 2018, some dasarian periods also showed pretty low rainfall, especially in the middle of April until October with a minimum value below 20 mm. That figure depicts that the higher concentration of PM 2.5 happens while the rainfall is low, compared to in February when the rainfall is so high.

Figure 5 shows the maximum PM 2.5 concentration is around 70-80 ug/m3. From May until December, Jakarta experienced substantially low rainfall, which was mostly below 50 mm. The higher concentration of PM 2.5 can be seen while the rainfall is low level. On the other hand, while the rainfall in a high level, PM 2.5 tends to be low. Therefore, it is most likely the higher the rainfall, the lower the PM 2.5 concentration and it is often during low levels of rainfall, that PM 2.5 concentrations tend to be high. Generally, the high concentration of PM 2.5 happened from May until October while the dry season occurred as mentioned by Sipayung [13] that the dry season occurs between June, July, August, September, and October. This can be caused by no scavenging effect in the dry season by the rainfall. Other research mentions that PM 2.5 decreased significantly through the scavenging of PM 2.5 from the atmosphere by precipitation. However, the precipitation duration was more influential in the reduction of PM 2.5 [14].

That might be also some abnormal situation which showed a high concentration of PM 2.5 while the level of rainfall was high or the contrary situation. This problem can be happened cause by averaging which is done on a daily basis (10 days) because there is a possibility that there is a bias that on certain days the rainfall is very high and on other days it is very bright and warm which has an influence on the PM 2.5 presence. On the other hand, transport pollutants and other meteorological factors can also influence the bias of data.

CORRELATION ANALYSIS

The quantitative results of the correlation analysis of PM 2.5 with rainfall in 2016-2019 are presented in Table 1.

TABLE 1: Results of correlation analysis of PM 2.5 compounds – Rainfall.

Year	P-value	R
2016	0.074	-0.094
2017	0.00018	-0.2
2018	3.40E-12	-0.35
2019	<2.2e-16	-0.52

The correlation coefficient is divided into five categories, namely the range 0-0.19 as the very weak category, the range 0.20-0.39 for the weak category, the range 0.4-0.59 included in the medium category, the range 0.6-0.79 for the strong category and the range 0.8-1 is included into the very strong category, whereas p-value that use in this research is 0.05. Therefore, the correlation from 2017 to 2019 is significant. In addition, the correlation that showed the strongest relation is data in 2019, -0.52. The R has a minus value, it represents that while rainfall increases, the 2.5 concentrations will decrease. It is in line with the explanation in part analysis of rainfall and PM 2.5.

CONCLUSIONS

According to the results, it is determined that the influence of rainfall on PM 2.5 presence in the atmosphere above Jakarta in the period between the years 2016 to 2019 for the dry season shows the scarcity of rainfall elevates the concentrations of PM 2.5 with the highest concentration around 60-80 μg m−3 and most likely when higher rainfall, the lower PM 2.5 concentration. This can be caused by no existing scavenging effect in the dry season by the rainfall. Moreover, there is a significant correlation between the precipitation levels and PM 2.5 concentrations, as evidenced by data in 2019, which exhibits an R-value of -0.52. It represents that while rainfall increases, the PM 2.5 concentrations will decrease. The study of precipitation duration influence must be conducted to understand the behaviour that occurs on PM 2.5 in Jakarta city.

REFERENCES

[1] N. T. Kim Oanh et al. (2006). "Particulate air pollution in six Asian cities: Spatial and temporal distributions, and associated sources. Atmos Environ, vol. 40, no. 18, pp. 3367–3380, Jun. doi: 10.1016/j.atmosenv.2006.01.050.

[2] Gavin Shaddick et al. (2018). Data Integration for the Assessment of Population Exposure to Ambient Air Pollution for Global Burden of Disease Assessment. Environ. Sci. Technol., pp. 9069–9078, doi: https://doi.org/10.1021/acs.est.8b02864.

[3] N. A. H. Janssen, P. Fischer, M. Marra, C. Ameling, and F. R. Cassee. (2013). Short-term effects of PM2.5, PM10 and PM2.5-10 on daily mortality in the Netherlands. Science of the Total Environment, vol. 463–464, pp. 20–26, Oct., doi: 10.1016/j.scitotenv.2013.05.062.

[4] R. T. Burnett et al. (2014). An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. 121 Environ Health Perspect, vol. 122, no. 4, pp. 397–403., doi: 10.1289/ehp.1307049.

[5] A. Zanobetti, F. Dominici, Y. Wang, and J. D. Schwartz. (2014). A national casecrossover analysis of the short-term effect of PM2.5 on hospitalizations and mortality in subjects with diabetes and neurological disorders. Environ Health, vol. 13, no. 1, 2014, doi: 10.1186/1476-069X-13-38.

[6] N. Fann, A. D. Lamson, S. C. Anenberg, K. Wesson, D. Risley, and B. J. Hubbell. (2012). Estimating the National Public Health Burden Associated with Exposure to Ambient PM 2.5 and Ozone. Risk Analysis, vol. 32, no. 1, pp. 81–95, Jan. doi: 10.1111/j.1539-6924.2011. 01630.x

[7] Queensland Government. (2017). Meteorological Faktors. Access form. https://www.qld.gov.au/environment/management/monitoring/air/air-monitoring/meteorology-influence/meteorology-factors

[8] BMKG. (2023). Daftar Istilah Klimatologi. Access form https://balai3.denpasar.bmkg.go.id/daftar-istilah- musim.

[9] Mukai, H., Ambe, Y., Shibata, K., Muku, T., Takeshita, K., Fukuma, T., Takahashi, J., Mizota, S. (1990). Long- term variation of chemical composition of atmospheric aerosol on the Oki Islands in the Sea of Japan. Atmos. Environ. A. General. Top. 24, 1379e1390. http://dx.doi.org/10.1016/0960-1686(90)90044-N.

[10] Chen, L.L., Carmichael, G.R., Hong, M.S., Ueda, H., Shim, S., Song, C.H., Kim, Y.P., Arimoto, R., Prospero, J., Savoie, D., Murano, K., Park, J.K., Lee, H.G., Kang, C., (1997). Influence of continental outflow events on the aerosol composition at Cheju Island, South Korea. J. Geophys. Res. Atmos. 102, 28551e28574. http:// dx.doi.org/10.1029/97jd01431.

[11] Park, M.H., Kim, Y.P., Kang, C.-H., Shim, S.-G. (2004). Aerosol composition change between 1992 and 2002 at Gosan, Korea". J. Geophys. Res. Atmos. 109, D19S13. http://dx.doi.org/10.1029/2003JD004110.

[12] N. Kineyasu et al. (2014). Impact of long-range transport of aerosols on the PM2.5 composition at a major metropolitan area in the northern Kyushu area of Japan. Atmospheric Environment. http://dx.doi.org/10.1016/j.atmosenv.2014.01.029

[13] S.B. Sipayung. (2011). Pemanfaatan Data Satelit Misat Untuk Identifikasi Awal Musim Kering di Indonesia. Majalah Sains dan Teknologi Digantara. Vol 6 No 1 Maret 2011:18-26.

[14] H. Ikeuchi et al. (2015). Scavenging of PM2.5 by precipitation and the effects of precipitation pattern changes on health risks related to PM2.5 in Tokyo, Japan Pubmed. doi: 10.2166/wst.2015.34