Climate factors affecting particulate matter 2.5 (PM2.5) in Bangkok, Thailand

A Harza[1*], R Piemjaiswang[2], S Kittipongvises[2]
{alia.harza@gmail.com}

[1]Environment Development and Sustainability Department, Graduate School, Chulalongkorn University, Thailand
[2]Environmental Research Institute, Chulalongkorn University, Bangkok, Thailand

Abstract. Every year, as many as 4.3 million children per year experience moderate respiratory diseases and several million more suffer from acute respiratory diseases due to air pollution. As policymakers, the public and scientists pay more attention to public health and clean air issues, the climate sector also provides several important instruments to encourage broader action. By using PM2.5 data, meteorology variable data, and Land use data. meteorological factors such as wind speed, temperature, humidity, precipitation, and visibility are used as factors that affect PM2.5, this is done statistically using multiple linear regression method and other statistical tests. Based on PM2.5 concentration data during 2019, it was found that the districts of Wang Thong Lang, Rat Burana, and Khan Na Yao were three districts that were included in the unhealthy category. all meteorological variables simultaneously have an effect of 47.3% on the concentration of PM2.5. visibility affects as much as 50% PM2.5 concentration with a negative correlation. The research shows that the higher the precipitation value, the lower the PM2.5 concentration. this may indicate that precipitation can purify/decrease the value of PM2.5 concentration. urban areas with low visibility, low temperatures, and low wind speeds may indicate that PM2.5 concentrations in the area are high. Lastly, it can be concluded that summer has higher PM2.5 concentrations than winter.

Keyword: Climate, affecting, particulate matter 2.5, Bangkok

1. Introduction

Urban areas are areas exposed to the highest concentrations of toxic pollutants, especially ambient air pollution. According to the World Health Organization report, over 80% of people living in urban areas are exposed to air pollutants that exceed WHO limits. Air pollution is a major risk factor and considered as one of the major global causes of mortality. Populations in low-incomes cities may face greater risks [1]. As many as 4.3 million children per year experience moderate respiratory diseases and several million more suffer from acute respiratory diseases due to air pollution [2]. In a big city like Bangkok, one of the factors causing air pollution is the rapid but not really sustainable development that has a domino effect on human life. The rapid increase in particulate matter 2.5 (PM2.5) concentration in Bangkok has reached its alarm level. As policymakers, the public and scientists pay more attention to public health and clean air issues, the climate sector also provides several important instruments to encourage broader action. Attention to air quality issues will help us achieve our health and climate targets.

SRICOENV 2022, October 05-06, Palembang, Indonesia

DOI 10.4108/eai.5-10-2022.2328342

Although rarely discussed, the fact is that air pollution and climate change are caused by some of the same factors. In some ways, these two issues are caused by the same chemical element. In other cases, health-damaging pollutants and climate change compounds are produced at the same time. Besides being influenced by the number of pollutant sources, the concentration of pollutant gasses in the air is also influenced by meteorological parameters, so that parameters such as wind speed, air temperature, and air humidity cannot be ignored. Climate change can directly affect air pollution by changing meteorological variables such as wind speed, wind direction, rainfall, and temperature [3]. As a result, pollutants will be trapped and accumulated in a certain area, which can worsen ambient air quality. The problem of air pollution in Bangkok is already kind of worrying because its impact can harm the environment and humans. Air pollution for the general city in the world, that comes from PM2.5 is contributed by congestion by 25 percent, 15 percent of industrial activities including power generation and 20 percent from domestic fuel combustion [4]. Meteorological variables such as air temperature, humidity, and wind direction and speed have an impact on the formation and dispersion of pollutants in ambient air [5] while rainfall plays a role in leaching of pollutants in the air [6]. Therefore, the overall objective of this study is to systematically assess the effect of climate factors on PM 2.5 impact in Bangkok, Thailand. The findings of this study will be useful for decision-makers and related to mitigate the impacts of climate-driven on PM2.5 contamination in in an environmentally sustainable manner.

2. Methodology

This study was conducted based on the following data: historical PM2.5 concentrations, meteorology, and land use data of Bangkok. To better understand the effects of climate factors on PM2.5 concentration, all related meteorological data, such as wind speed, temperature, humidity, precipitation, and visibility in Bangkok, were also examined.

2.1 Datasets

2.1.1 A Historical PM2.5 concentration

The daily mean concentrations of PM2.5 in Bangkok in 2019 and 2020 reported by the Bangkok Metropolitan Authority combined with data from Air Quality and Noise Management Division Bangkok were collected and analysed.

2.1.2 Meteorological data

The meteorological data used in this study was daily meteorological data in Bangkok, Thailand during 2019-2020. The following factors were gathered and investigated:

Wind Speed. The highest wind speed values were 29 knots in May 2020 and April 2019, while the lowest wind speed values were 2 knots and 3 knots in December 2020 and 2019 (with an average annual wind speed of 7 knots in 2019 and 2020).

Temperature. The highest temperature values in Bangkok were 27.8 ℃ in May 2020 and 29.7 ℃ in February 2019, while the lowest temperature values were 17.4 ℃ and 15.8 ℃ in December 2020 and 2019 (with an average annual temperature of 25 ℃ in 2019 and 2020).

Precipitation. The highest precipitation values in Bangkok were 54.2 mm in October 2020 and 64.8 mm in June 2019 (with a total annual precipitation of around 1124.4 mm in 2019 and 1295.3 mm in 2020).

Relative Humidity. The highest humidity values in Bangkok were 96% in June 2020 and 95% in September 2019, while the lowest humidity values were 44% and 48% in February 2020 and January 2019 (with an average annual humidity of 71% in 2019 and 2020).

Visibility. The highest visibility values in Bangkok were 21.250 km in December 2020 and 20.708 km in January 2019, while the lowest visibility values were 5.958 km and 5.917 km in January 2020 and the end of January 2019 (with an average annual visibility is 9.545 km in 2019 and 9.409 km in 2020).

Land Use. Land use map of Bangkok in 2019 derived from the Land Use Condition Analysis Group, Division of Land Use Policy and Planning, Department of Land Development is shown in Figure 1. Land uses in Bangkok were divided into 12 groups. Clearly, 54.48% of Bangkok's area is covered by community area and area building.

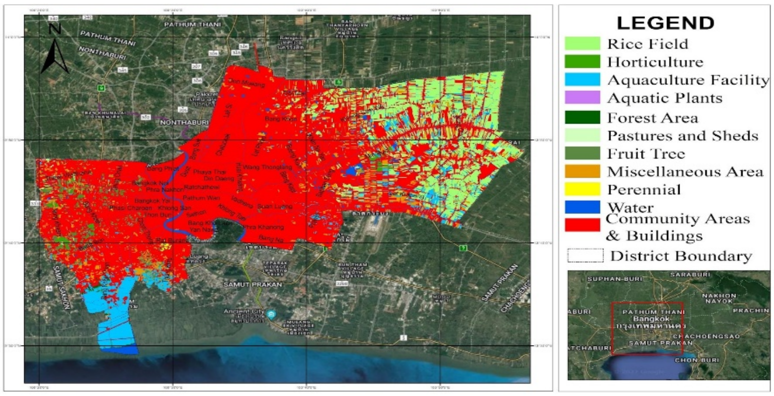

Figure 1. Land Utilization in Bangkok Province in 2019

Geographically, it should be noted that each category of area produces a different type of air pollutant. Combustion activities such as waste incineration, household combustion, motor vehicles and industrial production processes are one of the main sources of pollutants in Bangkok.

2.2 Data Analysis

2.2.1 Influence of meteorological variables on PM2.5 concentrations

In this study, the multiple linear regression method is used to determine the extent to which meteorological factors affect ambient PM2.5 concentrations. The statistical test in this study uses an error rate of 5% (α=0.05) or a confidence level of 95%. The test of the coefficient of determination is performed with the intention of measuring the ability of the model to explain how the influence of the independent variables simultaneously (simultaneously) affects the dependent variable, which can be indicated by the adjusted R-squared value (Ghozali, 2016). The coefficient of determination shows the extent to which the contribution of the independent variables in the regression model can explain the variation in the dependent variable.

2.2.2 Partial t-test and simultaneous F-test were also carried out.

For a partial t-test, if the value of Sig.<0.05, it means that the independent variable (meteorological variable) partially affects the dependent variable (PM2.5). Meanwhile, simultaneous F-test was used to determine the strength of all variables in influencing the dependent variable. Finally, the calculation is carried out to find out which variables have the most influence on the PM2.5 concentration value.

3. Result and discussion

3.1 PM2.5 concentrations in Bangkok

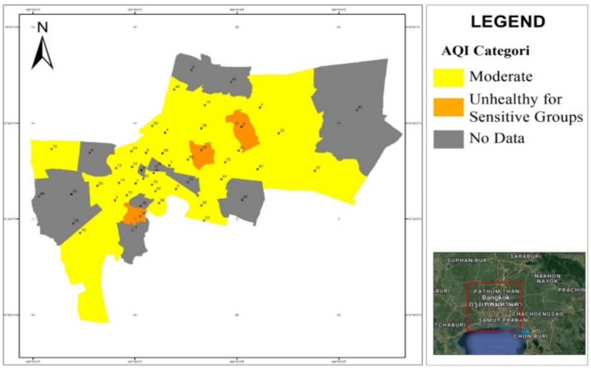

Figure 2. PM2.5 concentrations at Bangkok area in 2019

Based on PM2.5 concentration data in Bangkok, in each district, there is at least one PM2.5 measurement point. The average daily PM2.5 value in the Bangkok area per year is 24-36 µg/m3 (mean 29 µg/m3) in 2019 and 17-33 µg/m3 (average 23 µg/m3) in 2020. There was a decline in the average PM2.5 yearly in the Bangkok area from 2019 to 2020. During 2019, it was found that the districts of Wang Thong Lang, Ratburana, and Khan Na Yao were three districts that were included in the unhealthy category. Almost all other areas of Bangkok were included in the moderate category. In 2020, although it is not included in the unhealthy category, the Wang Thong Lang district is still the district with the highest PM2.5 concentration value compared to other districts. In 2020, the concentration of PM2.5 for the Bangkok area is in the moderate category.

Table 1. the U.S. EPA Air Quality Index for Particulate Matter.

Index Values	Category	Cautionary Statements	$PM_{2.5}$ ($\mu g\ m^{-3}$)	PM_{10} ($\mu g\ m^{-3}$)
0–50	Good	None	0–15.4	0–54
51–100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5–40.4	55–154
101–150	Unhealthy for sensitive groups	Sensitive groups should reduce prolonged or heavy exertion	40.5–65.4	155–254
151–200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5–150.4	255–354
201–300	Very unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5–250.4	355–424

Source: US EPA, 1997

3.2 Effect of meteorological variables on PM2.5 concentrations

3.2.1 F-test (ANOVA)

Table 2. ANOVA

MODEL	SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
REGRESSION	79415.753	5	15883.151	130.226	.000
RESIDUAL	88425.369	725	121.966		
TOTAL	167841.122	730			

a. Dependent Variable: PM2.5
b. Predictors: (Constant), Visibility, Wind Speed, Precipitation, Temperature, Humidity

The significance value of all meteorological factors is 0.000, which means that all meteorological factors affect PM2.5 simultaneously. The test of the coefficient of determination is performed with the intention of measuring the ability of the model to explain how the influence of the independent variables simultaneously affects the dependent variable, which can be indicated by the adjusted R-squared value. The coefficient of determination indicates the extent to which the contribution of the independent variable in the regression model is able to explain the variation in the dependent variable. According to Chin (1998), the coefficient of determination is indicated by the value of R-squared (R2) in the model summary table. The R-squared value is classified as strong if it is more than 0.67, moderate if it is more than 0.33 but less than 0.67, and weak if it is more than 0.19 but less than 0.33. The value of the coefficient of determination (R-squared) for the variable PM2.5 concentration is 0.473, which means that all independent/independent variables simultaneously have an influence of 47.3% on PM2.5 concentration. The remaining 52.7% are influenced by other variables that were not tested in the study.

Table 3. Effective Contribution and Relative Contribution of All related Climate Factors

VARIABLE	EFFECTIVE CONTRIBUTION	RELATIVE CONTRIBUTION
WIND SPEED	0.01	1.22
TEMPERATURE	0.12	25.72
PRECIPITATION	0.01	2.83
HUMIDITY	0.09	19.75
VISIBILITY	0.24	50.53

As shown in Table 3, visibility conditions were found to have the greatest influence on PM2.5 concentrations in Bangkok (50%), followed by temperature (25%) and humidity (19%). The meteorological variables that contributed least to PM2.5 concentrations were wind speed and precipitation. Daily mean PM2.5 concentrations in Bangkok in 2019 and 2020, as reported by the Bangkok Metropolitan Authority, were collected and analysed along with data from the Air Quality and Noise Management Division Bangkok.

This research was conducted based on the following data: historical PM2.5 concentrations, meteorology, and land use data of Bangkok. To better understand the impact of climate factors on PM2.5, all related meteorological data, such as wind speed, temperature, humidity, precipitation, and visibility conditions of Bangkok were also investigated.

4. Conclusion

There are various types and sources of pollutants in the air, one of which is PM2.5 as a type of pollutant. PM2.5 is one of the causes of many deaths from stroke, heart disease, respiratory infections, cancer and chronic lung disease. There have been many efforts made by the government in dealing with cases of increasing air pollution. One source of PM2.5 is industrial activities or vehicle emissions. Bangkok as a metropolitan area with 54.48% of its area filled with community and areas building certainly cannot be separated from the problem of its high concentration of PM2.5

Apart from these sources, this study aimed to find other factors that may affect the concentration of PM2.5. Meteorological factors and land use are two things that influence each other. changes in land use will eventually also affect meteorology in the region. The relationship between PM2.5 and meteorological factors is a mutually influencing relationship. During 2019-2020, meteorological factors affect PM2.5 concentrations by 47.3%. Each variable has its own relative contribution value, Visibility affects as much as 50% PM2.5 concentration with a negative correlation relationship. followed by Temperature, Humidity, Precipitation, and Wind speed in order from the largest to the smallest. all meteorological variables have a negative correlation with PM2.5 concentration.

This research can be a steppingstone for further research. because the higher the precipitation value, the lower the PM2.5 value. this indicates that precipitation can purify/decrease the value of PM2.5 concentration. the lower the temperature, the higher the value of PM2.5 so that in winter, the concentration of PM2.5 may be higher than in summer. urban areas with low visibility, low temperatures, and low wind speeds may indicate that PM2.5 concentrations in the area are of high value.

References

[1] World Health Organization, "Air pollution levels rising in many of the world's poorest cities.," Air pollution levels rising in many of the world's poorest cities, 2016.

[2] M. S. Zuhri, "Pengaruh Faktor-faktor Demografi Terhadap Emisi Udara di Indonesia," Jurnal Ilmu Ekonomi dan Pembangunan, vol. 14, no. 2, 2014.

[3] A. Dean dan D. Green, "Climate change, air pollution and human health in Sydney, Australia: A review of the literature," Environmental Research Letters, vol. 13, no. 5. 2018. doi: 10.1088/1748-9326/aac02a.

[4] D. Campbell-Lendrum dan A. Prüss-Ustün, "Climate change, air pollution and noncommunicable diseases," Bulletin of the World Health Organization, vol. 97, no. 2. 2019. doi: 10.2471/BLT.18.224295.

[5] M. A. Zoran, R. S. Savastru, D. M. Savastru, dan M. N. Tautan, "Assessing the relationship between surface levels of PM2.5 and PM10 particulate matter impact on COVID-19 in Milan, Italy," Science of the Total Environment, vol. 738, 2020, doi: 10.1016/j.scitotenv.2020.139825.

[6] H. Qi dkk., "COVID-19 transmission in Mainland China is associated with temperature and humidity: A time-series analysis," Science of the Total Environment, vol. 728, 2020, doi: 10.1016/j.scitotenv.2020.138778.