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Effects of $PM_{2.5}$ on the Incidence of Circulatory System Diseases in Muang District, Khon Kaen Province of Northeast Thailand

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Abstract

Air pollution is a major environmental hazard and is likely to have more severe effects on public health in the future. However, the data on the relationship of air pollution to health are still limited. This study aimed to analyze and quantify the long-term impact of the concentration of particulate matter, a diameter ≤ 2.5 μm ($PM_{2.5}$), in the ambient air meteorological factors, and circulatory system diseases registered in Muang District, Khon Kaen Province from 1 January 2015 to 31 December 2019. The results of the study showed that most of the patients (76,247) were males (60.36%), out of which a majority (66,482) were older people aged 65 years and above (52.63%). The analysis result of Poisson regression indicated that air pollutants and meteorological factors influenced the incidence rate of circulatory system diseases (CSDs) with statistical significance (p-value < 0.05). In addition, $PM_{2.5}$ caused a 1.0007 times increase in the incidence of CSDs (IRR = 1.0007; 95% CI = 1.0001-1.0013, p-value = 0.031). In other words, for every increase of 10 μg/cu.m. of $PM_{2.5}$, the corresponding increase in the incidence rate was 1.0070 times. Based on the epidemiological and statistical analysis, after controlling the other confounding factors, exposure to $PM_{2.5}$ increased the incidence rate of CSDs in Muang Khon Kaen. The results of this study could be used to assist local health authorities in taking preventative measures in the long run. Nonetheless, to fully comprehend the link between recurring occurrences and recurrent events, more study is required.

Keywords: Circulatory diseases; $PM_{2.5}$; Temperature; Relative humidity; Khon Kaen Province

1. Introduction

Nowadays, air pollution is a serious problem and a major health hazard due to population growth and the higher demand for consumption. This higher consumption demand leads to the growth of the industrial sector, which is the cause of air emissions. Climate change is also an important factor contributing to the accumulation of air pollution. The dust levels in Thailand currently exceed the Thailand Air Quality Standard in many provinces in northern, central, and northeastern areas including Bangkok and its surrounding areas and the tends to expand as a major problem to neighboring provinces in each region (Pollution Control Department, Ministry of Natural Resources and Environment, 2020). Khon Kaen is one of the provinces encountering the problem of $PM_{2.5}$ exceeding the World Health Organization's (WHO) guideline for 24-hr at 25 μg/m³ (World Health Organization, 2006). The major causes of this problem are transportation, the agricultural and industrial sectors, incineration in communities, etc. $PM_{2.5}$ affects the health and well-being of the

people in the area because it can reach the lower respiratory tract and lung alveoli that act as air exchange. Particulate matter (PM) has recently been associated with the risk for the development of circulatory system diseases (CSDs) in people from around the world (Zhang *et al.,* 2021). Thus, if fine particulate matter particles enter the respiratory system and cannot be filtered, they will enter the lower respiratory tract or may possibly enter the alveoli, resulting in lower air exchange and a more hard-working heart. This, in turn, has an effect on the other organs and the physical health of people. Previously, Amsalu et al. (2019) studied hospital admissions for cardiovascular diseases caused by the acute effects of $PM_{2.5}$ in Beijing, China using data based on the ICD-10 classification that was ischemic heart disease. The study demonstrated that with every 10 μg/m³ increase in $PM_{2.5}$, the admission for the treatment of ischemic heart diseases increased by 0.34%. According to Zhang *et al.* (2013), a study on outpatients with cardiovascular diseases in Gansu, China found that $PM_{2.5}$ was the reason for a 1.201 times increase in the risk of sexually transmitted ischemic heart diseases in men. The study of Nakhlé *et al.* (2015) found that $PM_{2.5}$ was the cause of a 1.02 times increase in the risk of morbidity with circulatory diseases. According to the study of Jiménez *et al.* (2009), $PM_{2.5}$ was associated with an increase in the mortality risk of circulatory diseases in the elderly over 75 in Madrid, Spain by 1.09 times.

In Thailand, circulatory diseases were listed in the top 5 highest rates of morbidity in 2017, 2018, and 2019. The rates of circulatory diseases per thousand of population in these years were 638.33, 604.77, and 682.99, respectively. In the northeastern region, it has been reported that circulatory system diseases were listed in the top 5 highest rates of morbidity in 2017, 2018, and 2019. The rates of circulatory diseases per thousand of population were 548.85, 501.11, and 583.86, respectively. Similarly, in Khon Kaen, circulatory system diseases have been listed in the top 5 highest rates of morbidity in 2017, 2018, and 2019. The circulatory diseases rate per thousand of population were 577.82, 485.76, and 619.04, respectively (MOPH Thailand, 2020a, 2020b, 2020c).

The previous studies have only focused on the concentration of air pollutants in Thailand and studies related to air pollution factors affecting circulatory system diseases is inadequate and there are no studies that associate these concentrations with long-term morbidity in the general population, let alone long-term morbidity due to circulatory system diseases. Similarly, there are no such studies for Khon Kaen Province. Accordingly, our first study sought to analyse and quantify the long-term impact of $PM_{2.5}$ on monthly overall circulatory system diseases in Muang District, Khon Kaen Province came into being.

2. Materials and Methods

2.1 Study area

The study site in Muang Khon Kaen is 16°26′ north latitude and 102°50′ east longitude of the part northeastern Thailand, covering an area of 953.4 km² (Figure 1).

2.2 Study design

Cohort studies have frequently associated long-term exposure to air pollution with health outcomes (de Souza *et al.,* 2012; Mann, 2003). This research is a retrospective cohort study as it is the most appropriate way of evaluating a condition's occurrence and natural history. This study were obtained the daily outpatient numbers of circulatory system diseases (from January 1, 2015 to December 31, 2019) from an individual outpatient database based on the standard structure of data on health, Ministry of Public Health. $PM_{2.5}$ and meteorological data from January 1, 2015 to December 31, 2019 in Muang District, Khon Kaen Province, these 60 months as the study period. The study subjects included all people who were diagnosed circulatory system diseases. These counts included total ischemic heart diseases (I20 - I25) and stroke (cerebrovascular diseases) (I60 - I69). The numbers of daily circulatory system diseases outpatient visits due to postoperative infection or accidents were excluded from the analysis and then the estimation equation for Poisson regression is given as follows:

$$\ln[E(Y)] = \alpha + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_p$$

E(Y) is the expected value of numbers of circulatory system diseases outpatients;α is the intercept; x_i is the $PM_{2.5}$ and meteorological factors, such as temperature, relative humidity, wind speed and air pressure; β is the regression coefficient.

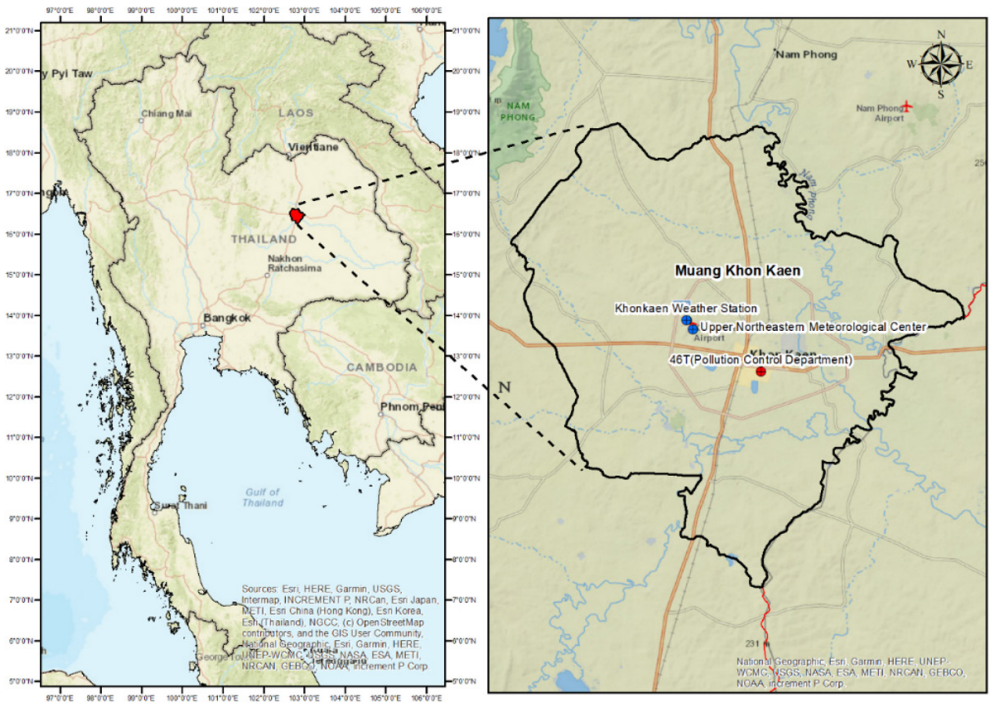

Figure 1. Map showing monitoring station for air quality and meteorological data in Muang Khon Kaen, Khon Kaen Province, Thailand

2.3 Data collection

This study collected secondary data from three sources: 1) data on hourly $PM_{2.5}$, measured in μg/m³, corresponding to the study period; the data were obtained from one station belonging to the Pollution Control Department (PCD), 2) the secondary data on hourly meteorological factor including temperature (°C), relative humidity (%), wind speed (knots), and air pressure (hPa) were obtained from the Thai Meteorological Department (TMD), Ministry of Digital Economy and Society., and 3) data on the daily number of circulatory system diseases registered were collected from outpatients number of circulatory diseases in the Muang District, Khon Kaen Province from January 1, 2015 to December 31, 2019 (60 months) from an individual outpatient database based on the standard structure of data on health, Ministry of Public Health (43 files) classified with the ICD -10 system e.g. ischemic heart diseases (I20 - I25) and stroke (cerebrovascular diseases) (I60 - I69) obtained from the Strategy and Planning Division, Office of the Permanent Secretary, Ministry of Public Health.

2.4 Statistical analysis

This research analyzed statistical data using the statistical software Stata/SE 15.0 (StataCorp LP) with a determined significance level of 0.05 for the descriptive statistics of the number of CSDs registered, $PM_{2.5}$, and meteorological data comprising frequency, mean, standard deviation, maximum (Max), minimum (Min) together with inferential statistics. These data typically follow a Poisson regression (Samet *et al.,* 2000); they were also used to determine the factors that influence the admission for treatment of circulatory system diseases with presenting in incidence rate ratios (IRR) and 95% confidence intervals (CI).

2.5 Research ethical consideration

This research study was approved by the Khon Kaen University ethics committee for human research based on the Declaration of Helsinki and Guidelines for Good Clinical Practice (ICH GCP), 28 January 2020, HE642047.

3. Results and Discussion

3.1 General characteristics of patients receiving circulatory disease treatment

The number of patients admitted with circulatory system diseases in Muang District, Khon Kaen Province during 1 January 2015 to 31 December 2019 was 126,319. Most of the patients (76,247) were males (60.36%). The monthly mean for males was 1,271 persons (SD = 313.42), and most of them (66,482) were older people aged 65 and above (52.63%). The monthly mean for older people aged 65 and older was 1,108 persons (SD = 276.75). More details of this result are shown in Table 1. The reason most of the patients receiving circulatory disease treatment in Muang District, Khon Kaen Province, were male (60.36%) was that females focused more on dust prevention and stayed home more compared to males. In addition, the occurrence of circulatory system diseases may also arise from other causes apart from air pollution, such as smoking behaviors that were more prominent in males than females.

3.2 Air pollutant concentration and meteorological data

In climatological data during 2015 – 2019 in Muang District, Khon Kaen Province, the monthly average $PM_{2.5}$ was 32.96 μg/m³. The average temperature was 27.31 °C. The average relative humidity was 70.33%. The average air velocity was 25.75 kts, and the average air pressure was 1068.8 hPa. These data are shown in more detail in Table 2. The changes in climate, temperature, relative humidity, wind speed, and air pressure are dependent on the seasons. During the winters, the weather is dry, cool, and stable, and temperature inversion is often found; it is like a sheet blocking the dust in the air from moving up. According to the study of Sakunkoo *et al.* (2020), most of the $PM_{2.5}$ during winter or from January to April exceeds the Guideline set by the WHO, which must not exceed 25 μg/m³ (World Health Organization, 2006) as during this time, in addition to climate fluctuation, sugarcane burning had to be finished by the middle of April as it was the sugarcane crushing season, which re-suspended particulate matters.

Table 1. Descriptive statistics of characteristics and patients registered with circulatory system diseases in Muang District, Khon Kaen Province from 1 January 2015 and 31 December 2019

Variables	Circulatory System Diseases						
	Number of CSDs (%)	Mean ± (SD)	Min	Number of CSDs cases			Max
				25th	50th	75th	
Total	126,319	2,105.32 ± 513.37	16	1,762	2,194	2,521	2,817
Sex							
Male	76,247 (60.36)	1,270.78 ± 313.42	10	1,064	1,307	1,509	1,700
Female	50,072 (39.64)	834.53 ± 202.41	6	712	892	969	1,117
Age (year)							
< 65	59,837 (47.37)	997.28 ± 238.97	7	865	1,034	1,180	1,311
≥ 65	66,482 (52.63)	1,108.03 ± 276.75	9	912	1,150	1,323	1,1522

Table 2. Descriptive statistics of $PM_{2.5}$ and meteorological data in Muang District, Khon Kaen Province from 1 January 2015 to 31 December 2019

Variables	Mean±(SD)	Min	Percentile			Max
			25th	50th	75th	
Concentration of $PM_{2.5}$ (μg/m³)	32.96 ± 16.21	10.70	18.74	29.53	43.40	68.62
Meteorological data						
Temperature (°C)	27.31 ± 2.05	22.58	25.54	27.48	28.47	32.41
Relative humidity (%)	70.33 ± 11.44	42.10	61.58	71.55	79.63	88.13
Wind speed (knots)	25.75 ± 5.85	12.23	21.75	25.45	30.33	39.61
Air pressure (hPa)	1068.80 ± 31.14	507.40	507.40	1039.20	1339.40	1638.40

3.3 Environmental factors affecting the incidence of circulatory system diseases

Table 3 shows the analysis results of factors affecting the incidence of circulatory system diseases, and shows that $PM_{2.5}$ caused a 1.0007 times increase in the incidence of system diseases (IRR = 1.0007; 95% CI = 1.0001-1.0013, *p*-value = 0.031). In other words, with every 10 μg/m³ increase in $PM_{2.5}$, the incidence of circulatory system diseases statistically increased by 1.0070 times. When controlling meteorological factors, gender, and age, the meteorological factors that contributed to the accumulation of $PM_{2.5}$ and the occurrence of circulatory system diseases were temperature, relative humidity, wind speed, and air pressure with statistical significance under controlled gender and age variables. The temperature caused a 1.0462 times increase in the circulatory system diseases (IRR = 1.0462; 95% CI = 1.0404-1.0519, *p*-value < 0.001). The relative humidity caused a 1.0058 times increase in the circulatory system diseases (IRR = 1.0058; 95% CI = 1.0048-1.0068, *p*-value < 0.001). The wind speed caused a 0.9951 times increase in the circulatory system diseases (IRR = 0.9951. 95% CI = 0.9939-0.9964, *p*-value < 0.001). The air pressure caused a 1.0041 times increase in the circulatory system diseases (IRR = 1.0041; 95% CI = 1.0036 -1.0045, *p*-value < 0.001).

This study found that $PM_{2.5}$ caused a significant increase by 1.0007 times in the incidence of circulatory system diseases under controlled meteorological factors and personal factors, including gender and age. This is consistent with a study by Zhang *et al.* (2013) on outpatients with cardiovascular disease in Gansu, China. The results revealed that $PM_{2.5}$ caused a 1.201 times increase in the risk of ischemic heart disease in males. Previous studies have reported the short-term effects of $PM_{2.5}$ on daily mortality due to circulatory system diseases in Madrid, Spain (Maté *et al.,* 2010). Additionally, the study of Nakhlé et al. (2015) found that $PM_{2.5}$ increased the risk of morbidity or possible mortality caused by a circulatory system disease by 1.02 times. The study of Jiménez *et al.* (2009) investigated $PM_{2.5}$ causing the risk of circulatory system diseases and daily mortality among the elderly over 75 years of age in Madrid, Spain. The result found that $PM_{2.5}$ increased the risk of mortality from circulatory system diseases by 1.088 times while meteorological factors showed that temperature caused a 1.0462 times increase in the incidence of circulatory system diseases. These results were also consistent with that of Pudpong (2008), who studied the short-term effects of air pollution and temperature on the daily illnesses in Chiang Mai, Thailand. It was found that an increase of 1 °C at each temperature above 29 °C resulted in a 19.2% increase in circulatory disease admission (Pudpong, 2008).

Table 3. Effects of $PM_{2.5}$ and meteorological factors on circulatory system disease admission of all population from 1 January 2015 and 31 December 2019

Variables	Circulatory System Diseases					
	Coef.	IRR	95% CI		z	*p*-value
			Lower	Upper		
$PM_{2.5}$ (μg/m³)	0.0007	1.0007	1.0001	1.0013	2.61	0.031*
Temperature (°C)	0.0451	1.0462	1.0404	1.0519	16.09	<0.001*
Relative humidity (%)	0.0058	1.0058	1.0048	1.0068	11.72	<0.001*
Wind speed (knots)	-0.0049	0.9951	0.9939	0.9964	-7.55	<0.001*
Air pressure (hPa)	0.0041	1.0041	1.0036	1.0045	19.41	<0.001*
Constant	-7.2455	0.0007	0.0006	0.0009	-63.21	<0.001

Note: * *p*-value <0.05, (Meteorological factors, gender, and age are controlled variables)
Incidence rate ratio (IRR)
Coefficient (Coef.)

This is consistent with the study conducted by Kiatchoosakun *et al.* (2021), which reported that temperature, surface pressure, and humidity are associated significantly with the incidence of new cardiovascular disease cases in Thailand. For the relative humidity, the incidence of circulatory system diseases was 1.0058 times higher. Similarly, a study conducted by Guiqin *et al.* (2020) in Shijiazhuang, China reported that for every 10 μg/m³ increase of $PM_{2.5}$, the risk of the increasing death toll from circulatory system diseases in Luancheng of the eastern plain was the highest at 11.9% (95% CI: 1.0071, 1.0168). Additionally, the study of Zeng *et al.* (2017) supported that mortality with circulatory system diseases was found in high humidity rather than low humidity. Furthermore, wind speed caused a 0.9951 times increase in the incidence of circulatory system diseases. In the case of $PM_{2.5}$, high wind speed might cause air pollution dilution and result in reduced disease as well. At the same time, if the wind speed was low, it could not be able to discharge pollutants, so the pollution concentration and pollutant potential would become higher. In terms of air pressure, it caused a 1.0041 times increase in the incidence of circulatory diseases. According to Danet *et al.* (1999), a 10-mbar increase in atmospheric pressure was associated with an 11% increase in the incidences of cardiovascular diseases. Furthermore, the study conducted a meta-analysis has evidence reported that long-term $PM_{2.5}$ exposure and risks of ischemic heart disease (IHD), cerebrovascular mortality, and incident stroke (Alexeeff *et al.,* 2021). Thus, if air pollution was improved and controlled rightly, the incidence of circulatory system diseases would be decreased.

3.4 Limitation of this study and suggestions

As this study uses secondary data, there were limitations in collecting health and environmental data regarding completeness and accuracy. Additionally, with (especially anonymous) survey data, once a sample is collected it is frequently impossible to go back and obtain missing or additional sources of data. For example, patient demographical details were not collected in early surveys; this problem has since been rectified (Weinger *et al.,* 2003), which may lead to inaccurate analysis of data. Therefore, the further study should consider the confounding variables that may affect the statistical analysis, such as occupation, smoking, alcohol consumption, and underlying diseases etc. In terms of environmental data, there have been a limited number of automatic quality measurement stations, so $PM_{2.5}$ monitoring points should be added covering many areas for analyzing data appropriately on health of people in each area.

4. Conclusion

This study aimed to analyze and quantify the long-term impact of the concentration of $PM_{2.5}$, meteorological factors, and circulatory system diseases registered in Muang District, Khon Kaen Province from 1 January 2015 to 31 December 2019. The results of the analysis of factors affecting the incidence of circulatory system diseases found that $PM_{2.5}$ caused the incidence of circulatory disease to increase by 1.0007 times (IRR=1.0007; 95% CI=1.0001-1.0013). In other words, with every increase of 10 μg/m³ of $PM_{2.5}$ the corresponding increase in the incidence rate was 1.0070 times. $PM_{2.5}$ levels are a major risk factor for circulatory system diseases. Planning and implementing particular initiatives efforts to decrease these levels is a critical issue from the perspective of public health. As a result, efforts to regulate, prevent, and enhance people's awareness and comprehension of various elements or causes for better self-protection should be implemented.

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