

Impact of Particulate Matter 2.5 During Covid-19 in Bangkok, Thailand

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Abstract

Bangkok is a large city with severe Particulate Matter 2.5 (PM_{2.5}) and traffic congestion problem. In past decades, traffic was the main cause of PM_{2.5}. Due to the Covid-19 pandemic in 2020, Bangkok was in lockdown which substantially decreased traffic volume during that period. In this research, the author studied how this change in Bangkok's traffic volume affected the concentration of pollution, especially PM_{2.5}. Data were collected from 63 points in Bangkok and on 4 highways during January 2018 to December 2023. The analysis showed that during the lockdown period, the concentrations of PM_{2.5}, NO_x, NO₂, NO and CO decreased by 14.38%, 12.93%, 18.43%, 2.65% and 5.66%, respectively, while traffic volume decreased by about 40%. However, there was no significant relationship between the concentration of PM_{2.5} and the decreased traffic volume. Therefore, the results indicated that while the Covid-19 pandemic might have influenced the change in traffic volume, it was not the main cause because the effect of season on PM_{2.5} outweighed the impact of traffic volume.

Keywords: Traffic; PM_{2.5}; Covid-19 pandemic; Bangkok; Thailand

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1. Introduction

The US EPA (United States Environmental Protection Agency) [1] has set a standard for small particles which are harmful to human health based on a particulate matter (PM) rating. For example, PM₁₀ or coarse particles defines the small particles found in dust and smoke, which have a diameter in the range 2.5–10 microns that can be clearly seen. However, PM_{2.5}, or fine particles, are tiny, having a diameter of 2.5 microns and below.

There is substantial evidence and many studies all over the world that have shown that traffic is the main factor contributing to PM_{2.5} [2]–[7]. Currently, PM_{2.5} pollution has become a severe problem in Thailand, especially in metropolitan areas, such as Bangkok, Chiangmai, Chiang Rai and Lampang [8], [9]. In addition, extreme traffic congestion in Thailand is still a concern, with Bangkok having consistently bad traffic jams over a long period [10], [11]. From the beginning of 2020, the Covid-19 pandemic changed people's behavior. In many countries, cities were locked down to reduce the opportunities for the virus to spread, which catalyzed online learning and working from home. This lockdown policy not only had economic impacts but also restricted activities in communities, such as major reductions in traveling and changing the mode of transportation in many countries [12]–[14]. In particular, on Bangkok's highway, during the worst of the Covid-19 period, traffic volume decreased by about 40% and the number of people using public transportation fell by 50% [15], [16]. Authors questioned the relationship

between the decrease in traveling and air pollution.

The current research separated statistical data 2015 and 2021 into 2 periods, with the first set the Covid-19 pandemic (from 2015 to 2019) and second during the pandemic (2020 to 2021) [17]. Statistical methods were applied to compare the data in same the period range [16] as well as to study how traffic volume and air pollution were related, especially the impact of the PM_{2.5} concentration level on changing traffic volume.

2. Other Studies

Particulate matter is made up of particles (tiny pieces) of solids or liquids that are in the air. It may include dust, dirt, soot, smoke and drops of liquid (aerosols). It may occur from natural sources, such as dust and pollen, but also can arise from human activities, such as industrial processes, working machinery (including internal combustion engines), electrical generation processes, and construction, mining and agricultural activity [18]–[20], lead to the release of PM_{2.5} material into the atmosphere that is sourced from releasing elementary particles and changes in initial substances, such as SO₂, NO_x, VOCs and NH₃ in the primary releasing stage [21]–[24]. In addition, PM_{2.5} material can include not only toxic but also long-lasting components that continue to pollute the environment. Furthermore, PM_{2.5} can travel long distances due to atmospheric circulation. In summary, the combination of these factors makes PM_{2.5} material extremely harmful to human health [25], [26].

2.1 PM_{2.5} in Thailand

The Pollution Control Department has estimated that the number of deaths in Thailand caused by PM_{2.5} may have reached 22,000 in 2021 [27] as the Thailand air quality index (AQI) from the beginning of 2021 [28], including the concentration level of PM_{2.5} was exceedingly high. Main factors influencing the level of PM_{2.5} are human activities especially from transportation—smoke from exhaust pipes and emissions from the incomplete combustion of gases in the engine—which were the main sources of PM_{2.5} in Bangkok, Chiang Mai and Khon Kaen [9].

In addition, high density traffic results in high PM_{2.5} levels. Thailand was ranked fifth in the Asian region after Indonesia, Myanmar, Vietnam, and Laos, respectively [8]. In 2021, Lampang had the highest level of PM_{2.5} in Thailand. PM_{2.5} levels in Thailand are heavily influenced by dust and air pollution related to seasonal activities, especially in the Chiang Mai river basin due to particles from burning agricultural waste to prepare for the next rice harvest in the subsequent rainy season. These agricultural areas are in valleys where the landscape is suitable for PM_{2.5} accumulation [29]. The PM_{2.5} problem is especially bad during the dry season in northern rural areas, such as Chiang Mai, Lampang and Nan provinces, where the [pollution seems to have become increasingly severe in recent times [30], [31]. Research studies on the causes of PM_{2.5} in community areas, such as Bangkok, found there were higher levels of PM_{2.5} in the dry season compared to the wet season.

The most common sources of PM_{2.5} emissions in Bangkok are biomass combustion and traffic, and industrial activities, with varying concentrations based on seasonal factors [32]–[34]. A study on pollutant concentrations for O₃, NO_x, CO and SO₂ from 1996 to 2009 in Bangkok reported that for residential area and roadside locations, the winter air pollution concentrations were higher than in summer and rainy seasons, with the roadside areas having higher levels than the residential areas in Bangkok [35].

2.2 Transportation and PM_{2.5}

Road transportation is a source of pollutants, such as O₃, CO, NO_x, and NMVOC, along with the greenhouse gases (CO₂, CH₄ and N₂O), acidic substances (NH₃ and SO₂) and carcinogens (polycyclic aromatic hydrocarbons (PAHs) and Persistent organic pollutants (POPs)) as well as toxic heavy metals [36]. Over past period, transportation and travel-related activity were the main cause of PM_{2.5} in urban areas. A study in China on the impacts of freight transport on PM_{2.5} concentrations showed that switching the mode of goods transportation from road freight to sea freight helped to significantly reduce the PM_{2.5} level in rural areas [37]. Another research study on alternative transport options in Adelaide, South Australia using modeling found that the PM_{2.5} level was directly proportional to Vehicle-Kilometers Traveled (VKT), with a decrease of 40% decreasing the PM_{2.5} level by 0.4 µg./m³. In other words, shifting transportation modes from road to other forms could help in reducing the PM_{2.5}

level [38]. A study in Pittsburgh, USA on trace elements found that the concentration of pollutants, such as As and Se, during rush hours was higher than during other periods in the week [39]. The above research results show that in the transport sector, especially road transport, the higher the traffic density, the more it affects the occurrence of PM2.5.

2.3 Transportation and PM2.5 during Covid-19 pandemic

In Wuhan, China on December 2020, the WHO China Country office reported cases of pneumonia of unknown etiology [40] that was later confirmed by WHO as an emerging infectious disease defined as coronavirus disease 2019 (COVID-19) [41]. Thailand declared a state of emergency on 26th March 2021, leading to a partial lockdown of Bangkok and surrounding areas. Although the number of infected cases in other areas continuously increased as a result of worker immigration, the number of confirmed cases never exceeded 200 per day. The Covid-19 situation in Thailand remains under control; however, there are uncertain factors and there is the risk of outbreaks. Therefore, the government issued prevention measures and continues to closely monitor the situation [9]. Throughout the Covid-19 pandemic (January 2019 to August 2022), Thailand took preventive and proactive measures as the situation unfolded. Then, Covid-19 was declared endemic, and Thailand has reopened its borders to tourists after a long period of closure. Countermeasures applied, from the first infection until 2021 (when the situation unfolded), are provided in **Table 1**.

Table 1 Preventive measure for handling Covid-19 in Thailand.

Measure	Wave				
	1 st	2 nd	3 rd	4 th	5 th
Restriction on entering high-risk infected areas	•	•	•	•	
Curfew 9.00pm–04.00am				•	
Working from home and online learning	•	•	•	•	
Restriction on opening times for shopping malls and markets	•	•	•	•	
Parks and entertainment places closed	•	•	•	•	
Border closed	•				
14 days quarantine on international arrival		•	•	•	•
Availability of 1 st dose of vaccine (Aug. 2021)				•	
Availability of 2 nd dose of vaccine					•

1st wave, Mar 2020–Jun 2020; 2nd wave, Dec 2020–Jan 2021; 3rd wave, Apr 2021–May 2021; 4th wave Jun 2021–Dec 2021; and 5th wave, Jan 2022–May 2022.

Fig. 1 shows the number of infected cases from January 2020 to June 2021. During the 1st and 2nd waves of Covid-19, there were low numbers of new infected cases per day because of the quarantine policy when Covid-19 was an emerging disease, with no developed vaccine. However, after some people had received a vaccination and returned to living a normal life, they became familiar with the Covid-19 situation and were less careful and ignored some of the preventative measures. This led to new waves (3rd and 4th) of Covid-19, resulting in increased numbers of infected cases over a short period. Concurrently, Covid-19 had evolved to

produce mutations that were more severe and more rapidly transmitted.

Therefore, during the 4th and 5th waves, the numbers of infected cases increased to 10,000 per day before continuously declining. Finally in July 2022, the Ministry of Public Health, Thailand declared the Covid-19 situation to

be fully controlled and Covid-19 was downgraded from pandemic to endemic status. However, the Covid-19 pandemic changed the travel behavior of people globally. In Europe, research in Spain (Mobility Patterns: The First Wave's Results) [42], provided evidence of changing travel behavior.

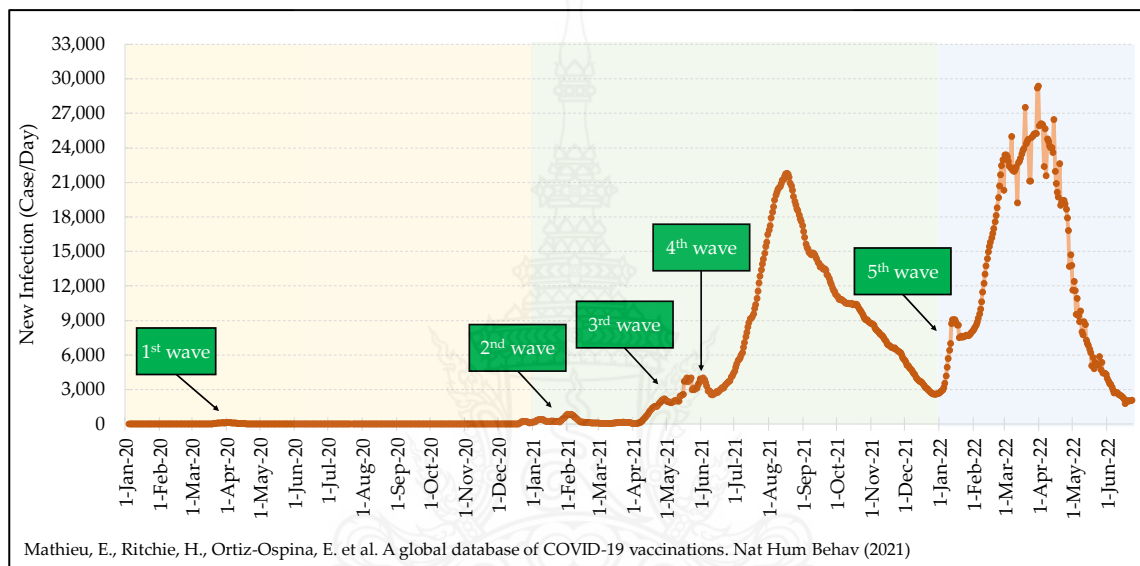


Fig. 1 Overview of number of Covid-19 infections (cases/day) in Thailand January 2020–June 2021

3. Methodology and Motivation

The meteorological dataset used in this research contained air pollution and statistical data of expressway traffic volumes in Bangkok. These data were used to identify the correlation between traffic volume and the PM2.5 level during the Covid-19 pandemic. Daily data were obtained from the Bangkok Pollution Control Department and the Expressway Authority, from January 2015 to December 2021.

3.1. Statistical data of meteorology and air pollution

In this research, the meteorological and pollution data of Bangkok areas were

collected at the points shown in **Fig. 2** based on 2 sources totaling 66 stations: 12 stations from the Pollution Control Department (green points in **Fig. 2**) and 50 stations from the Environment Bureau Bangkok (red points in **Fig. 2**). These inspection tools are aligned to the announcements of the Pollution Control Department [43] (Measuring Instruments and Methods for Measuring Average Gases or Particulates in the Atmosphere in General Other Systems or other Methods Approved). The instruments are permanently installed 2 meters above ground level.

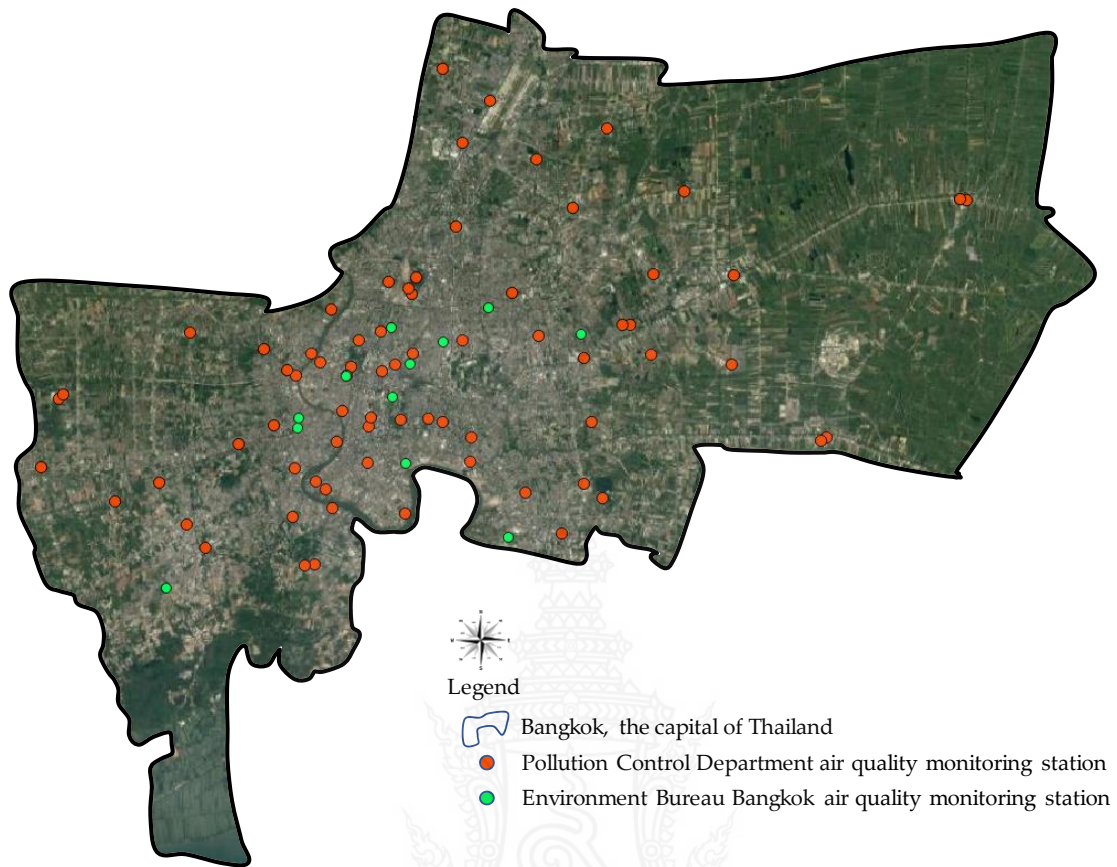


Fig. 2 Air monitoring stations of Pollution Control Department (50 red points) and Environment Bureau Bangkok (13 green points)

The meteorological dataset consisted of more than 2.3 million measured values for PM_{2.5} (fine dust particles with a size less than 2.5 microns), coarse particles (PM₁₀), nitrogen oxide (NO_x), nitrogen dioxide (NO₂), nitric oxide (NO), carbon monoxide (CO), wind speed (WS), wind direction (WD), temperature (Temp), barometric pressure (BP), relative humidity (RH%), and ozone (O₃) from 1 January 2015 to 31 December 2021. Hourly measurements were taken using

appropriate instrumentation and the results were reported according to standard values. For example, PM_{2.5} values were collected every hour and then averaged to provide a 24-hour average that was compared with standard values. The measurement and sampling methods followed the Federal Equivalent Method standards. **Fig. 3** shows an example of some of the dataset used in this study. **Table 2** provides a summary of the raw data obtained from various organization during the study period.

Key_mth	Hour	WS(m/s)	WD(Deg)	Temp(Deg.C)	RH(%)	BP(mBar)	CO(ppm)	NO(ppb)	NO2(ppb)	NOX(ppb)	O3(ppb)	PM10(ug/m3)	PM2.5(ug/m3)
20210101.0	1.0	1.2	81.0	22.8	57.0	763.0	0.85	7.0	20.0	27.0	22.0	43.0	15.0
20210101.0	2.0	0.8	78.0	22.2	59.0	762.0	0.99	14.0	22.0	36.0	18.0	45.0	23.0
20210101.0	3.0	0.6	83.0	21.6	62.0	762.0	0.98	9.0	21.0	30.0	18.0	45.0	21.0
20210101.0	5.0	0.6	32.0	20.9	62.0	762.0	0.92	11.0	21.0	32.0	15.0	46.0	33.0
20210101.0	6.0	1.2	342.0	20.2	61.0	762.0	0.86	18.0	24.0	42.0	13.0	42.0	32.0
20210101.0	7.0	0.5	8.0	19.9	63.0	763.0	1.01	40.0	33.0	73.0	7.0	38.0	28.0
20210101.0	8.0	0.6	6.0	20.0	64.0	764.0	1.06	59.0	33.0	91.0	6.0	41.0	27.0
20210101.0	9.0	0.8	46.0	20.5	64.0	765.0	1.04	49.0	33.0	80.0	10.0	47.0	28.0
20210101.0	10.0	0.9	13.0	21.8	60.0	765.0	1.02	44.0	28.0	71.0	14.0	52.0	33.0
20210101.0	11.0	1.1	22.0	23.3	56.0	765.0	1.01	32.0	28.0	60.0	18.0	52.0	33.0

Fig. 3 Example of dataset used in this study

Table 2 Summary of data sources

Data Source	Number of stations	Data records (2015–2021)
Pollution Control Department air quality monitoring station	13	787,550
Environment Bureau Bangkok air quality monitoring station	50	1,516,342
Total	63	2,303,892

Then, a data cleansing process was conducted to obtain the final data used in the analysis. Data within the 99th percentile were used. This meteorological dataset was used to help not only identify influential factors of pollution sources regarding air quality but also to help directly reduce pollution from the origin source [44], [45].

The meteorological data were separated into 2 datasets: 1) before the Covid-19 pandemic (2015–2019); and 2) during the Covid-19 lockdown. (2020–2021) **Table 3** provides an overview of the various pollution concentrations before the Covid-19 outbreak and during the lockdown. The authors compared the hourly average pollution concentration data from the 63 monitoring stations in Bangkok.

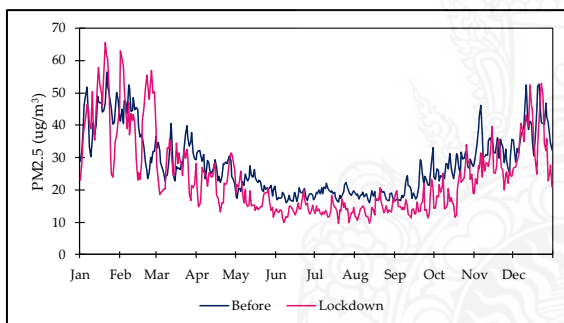
There were differences and trends in the air pollution concentrations before the Covid-19 epidemic and during the lockdown. During the Covid-19 outbreak, the average values for PM2.5, NO_x, NO₂, NO and CO were lower than before the Covid-19 outbreak, while the average PM10 and O₃ values increased during the Covid-19 outbreak.

During the lockdown period, there were fewer cars on roads. Mobility was restricted and most people stayed at home. During this time, the concentrations of PM2.5, NO_x, NO₂, NO and CO decreased by 14.38, 12.93, 18.4, 2.65 and 5.66%, respectively. In addition, we compared the average hourly concentration of air pollution before the pandemic and during the lockdown period.

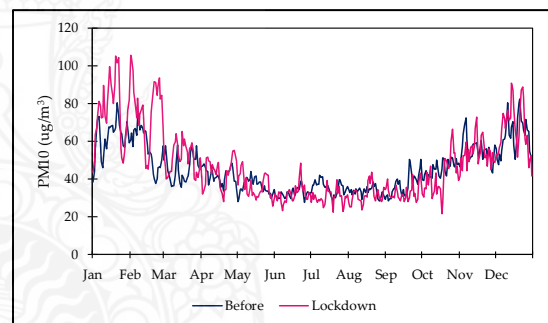
Fig. 4 (a) PM2.5, (b) PM10, (c) NO_x, (d) NO₂, (e) NO, (f) CO and (g) O₃ show the concentration values of each parameter after analysis and compared with the concentration of pollution in the dry season, from November to March for both before the pandemic and during lockdown period; the concentration levels of pollution in both periods were in the same direction.

Table 3 Statistical data on air pollution used in this study

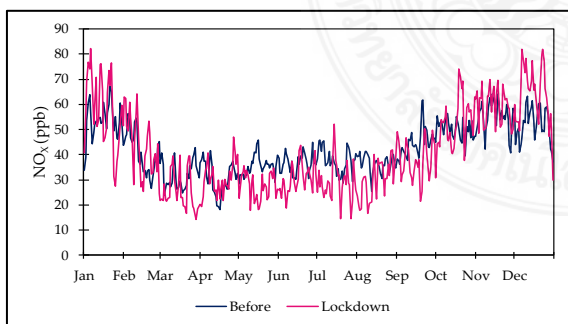
Factor	Before Covid-19 pandemic		During lockdown period		Difference (%)
	Mean	SD	Mean	SD	
PM2.5 (ug/m ³)	27.93	18.94	23.92	16.21	-14.38
PM10 (ug/m ³)	44.97	26.19	47.45	27.94	5.51
NO _x (ppb)	42.15	40.88	36.70	41.32	-12.93
NO ₂ (ppb)	22.15	15.10	18.07	14.35	-18.43
NO (ppb)	23.00	32.96	22.39	33.93	-2.65
CO (ppm)	0.85	0.55	0.80	0.55	-5.66
WS (m/s)	0.84	0.66	0.65	0.52	-23.40
WD (°)	188.56	92.74	186.22	97.33	-1.24
Temp (°C)	29.42	2.92	29.18	3.09	-0.82
BP (mBar)	869.66	59.13	978.40	83.61	12.50



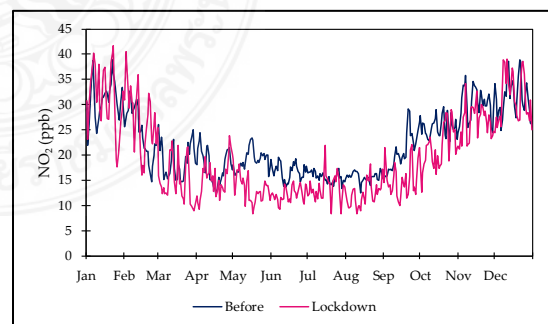
(a)



(b)



(c)



(d)

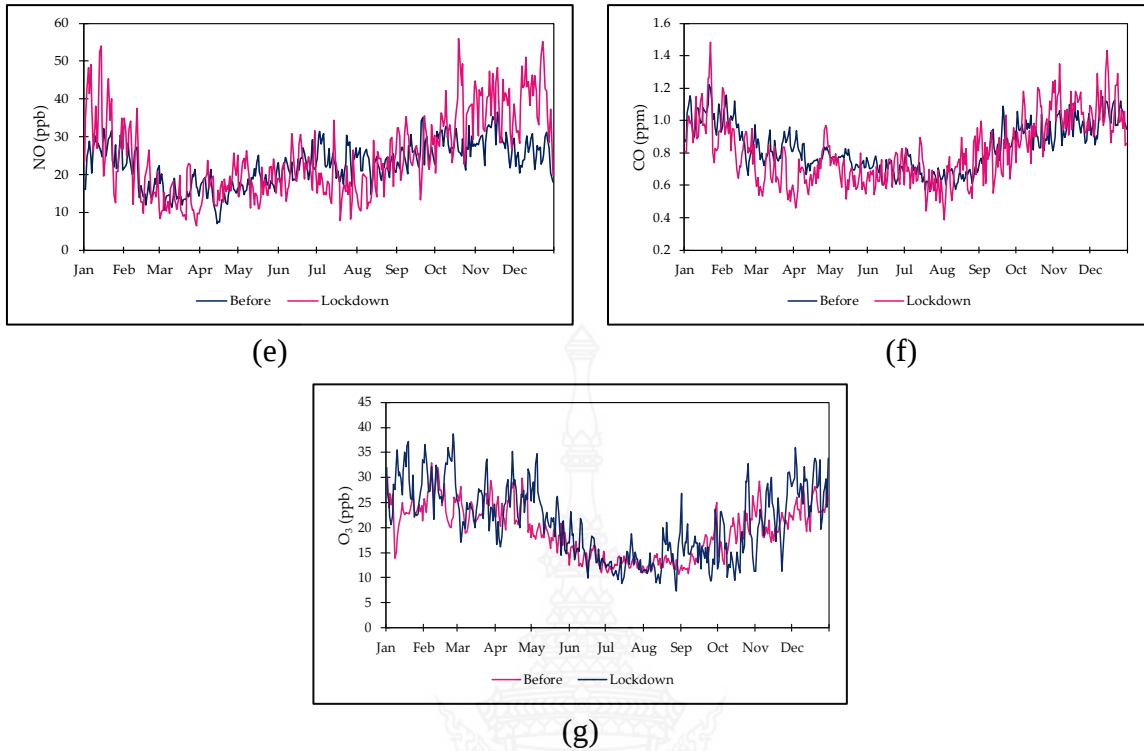


Fig. 4 Hourly average concentration levels of each parameter before period of Covid-19 pandemic and during period of lockdown: (a) PM2.5; (b) PM10; (c) NO_x; (d) NO₂; (e) NO; (f) CO; (g) O₃

3.2. Kruskal-Wallis test

The Kruskal-wallis one-way analysis of variance method was used to identify the characteristics of the distribution of the time series data [46], [47]. The Kruskal-Wallis method is commonly used for identifying the distribution of air pollution data and has been proven effective at monitoring seasonal distribution data of air quality and dominant air pollutants [48], [49]. Initially in the characteristic distribution testing, the pollution data characteristic was assumed to be seasonal using the hypotheses:

- H0: Median value of each pollution parameter is equal every month.
 H1: Median value of each pollution parameter differs for at least 1 month.

H was calculated using equation (1):

$$H = \left[\frac{12}{n(n+1)} \sum_{j=1}^c \frac{r_j^2}{n_j} \right] - 3(n+1) \quad (1)$$

based on the sum of sample sizes for all samples (n), the number of samples (c), the sum of ranks in the j^{th} sample (T_j) and the size of the j^{th} sample (n_j).

Table 4 shows the results, indicating that the median of each pollution parameter differed in at least 1 pair in each monthly result, with a P-value lower than 0.05. Therefore, hypothesis H1 was accepted that pollution parameters each month before the pandemic and during the lockdown period were significantly different.

Table 4 Results of Kruskal-Wallis test on pollution parameters (January 2015 to December 2021)

Parameter	Statistic	
	H statistic	Asymp. Sig.
PM2.5 (ug/m ³)	48.57	0.000
PM10 (ug/m ³)	49.37	0.000
NO _x (ppb)	28.62	0.000
NO ₂ (ppb)	28.94	0.000
NO (ppb)	44.48	0.000
CO (ppm)	36.69	0.000
O ₃ (ppb)	48.47	0.000

In summary, the concentration of PM2.5 was significantly influenced by seasonal factors.

Some research has shown that decreasing road traffic volume is not the major cause of decreasing air pollution, with general human activity more directly related to the pollution level [50]. Nonetheless, research in Italy [51], studying the correlation between road traffic and air pollution, indicated the effect of traffic on the

concentration of air pollution; however, the research focus was on NO, NO₂ and NO_x (PM2.5 was not mentioned). Therefore, it was not possible to utilize that study to determine conclusively the relationship between traffic and the concentration of PM2.5.

3.3. Relationship between traffic density and PM2.5

The daily traffic data in the metropolitan area, shown in **Fig. 5**, covered the Chalm Maha Nakhon Expressway, the Si Rat Expressway, Chalong Rat Expressway and the Burapha Withi Expressway. The travel data showed that under normal conditions, the traffic volume on these expressways reached 1.78 million vehicles per day. However, during the lockdown period (2020–2021), the traffic volume on expressways dropped to 1.36 million vehicles per day.

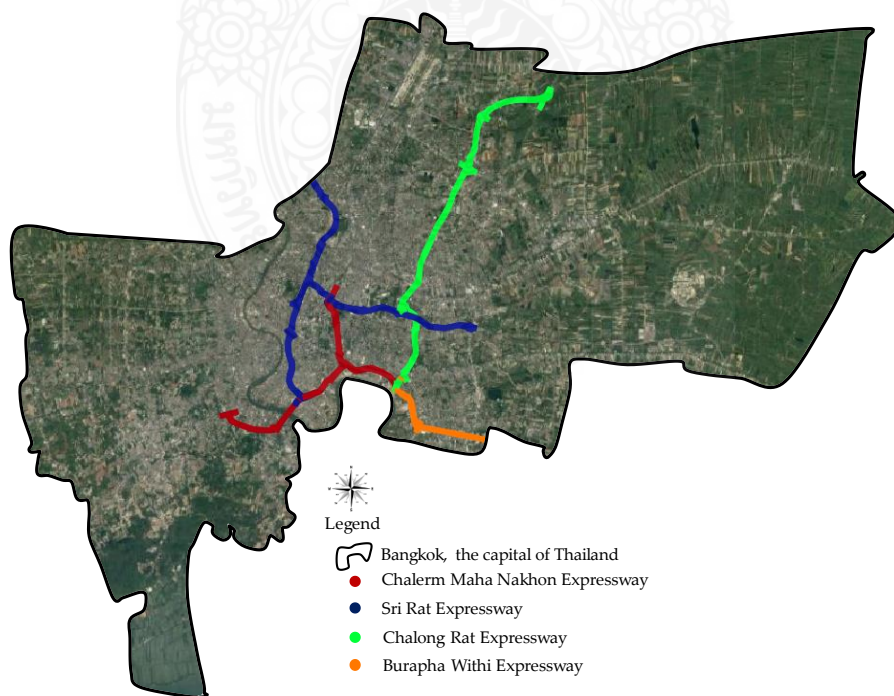


Fig. 5 Overview of 4 urban expressways in Bangkok

In **Fig. 6**, the daily volume of vehicles is separated into 2 periods: before the Covid-19 pandemic (January 2015 to December 2019), and during the Covid-19 outbreak (January 2020 to December 2021). In Thailand, the Covid-19 pandemic began in January 2020, with the lockdown

that prohibited people from going out for non-essential activities being implemented from April to June 2020 and was considered to be most effective as indicated by the approximately 40% reduction in travel volume that occurred during this time.

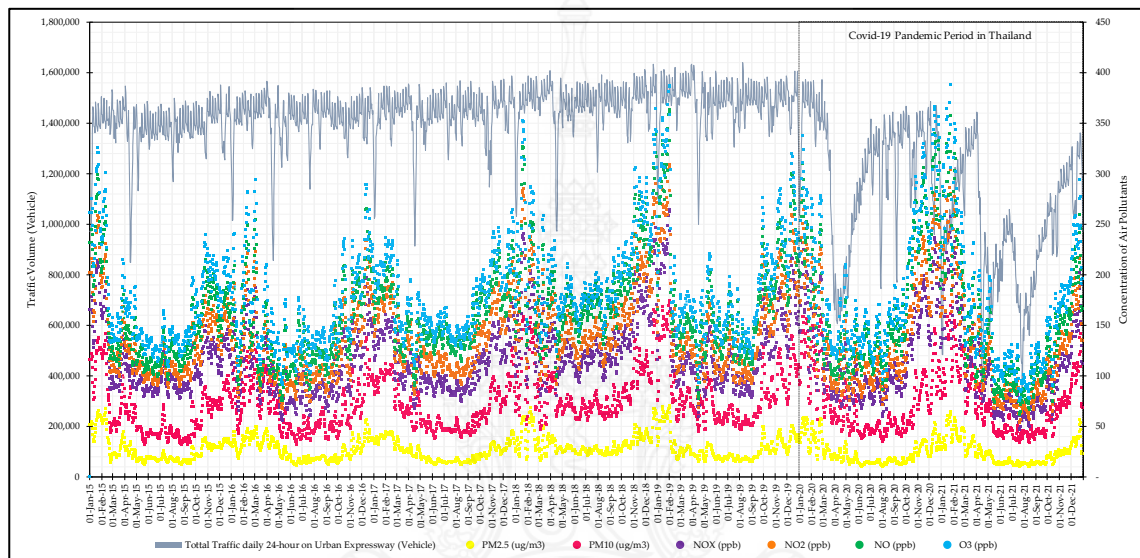


Fig. 6 Daily traffic volume and concentration of air pollution during 2 periods: before Covid-19 pandemic (January 2015 to December 2019) and during Covid-19 outbreak (January 2020 to December 2021)

4. Results and Discussion

Considering relationship between traffic volume and PM2.5 in Figure 7, before the Covid-19 pandemic (January 2015 to December 2019), the traffic volume each day was generally within the same range, while the PM2.5 concentration level depended on seasonal factors. In every year, PM2.5 was the highest in the dry season (November to March).

During the Covid-19 pandemic, the implementation of a lockdown caused the traffic volume to rapidly decrease (from March 2020). Considering only the data before March 2020, the data is misleading, suggesting that PM2.5 and traffic volume

are strongly related. However, considering all the data in this research (from 2015 to January 2021), it was during the dry season that there was a 5th wave of Covid-19 which reduced the traffic volume again. The analysis showed that when the PM2.5 level was highest it resulted in an inverse effect on the traffic volume, especially during the dry season (January) when traffic volumes were reduced but the PM2.5 level was noticeably higher (square box highlighted in yellow in **Fig. 7**).

In addition, the statistical data showed that the correlation coefficient between traffic volume and the concentration of PM2.5 was 0.206.

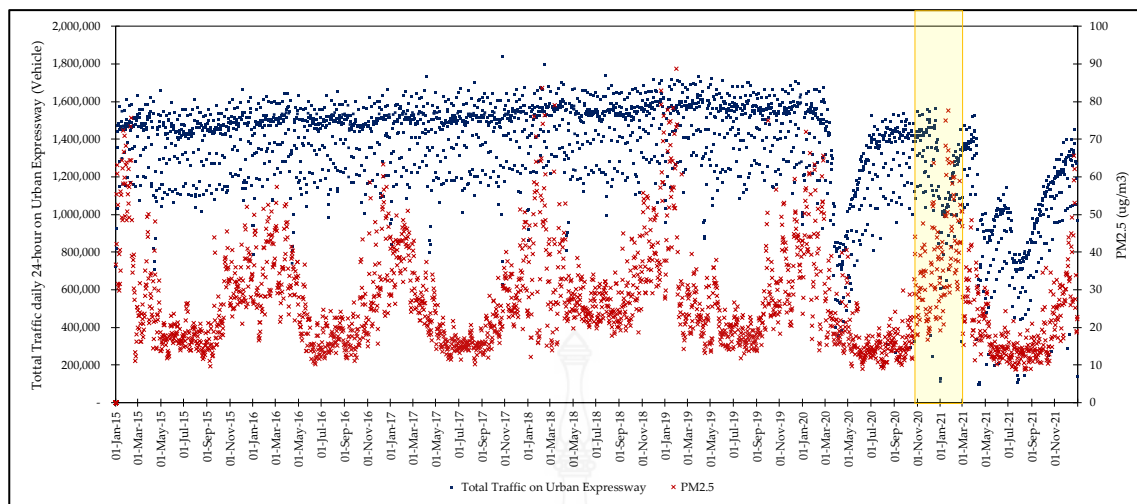


Fig. 7 Daily traffic volume and concentration of PM_{2.5} in 2 periods: before Covid-19 pandemic (January 2020 to December 2019), and during the Covid-19 outbreak (January 2020 to December 2021)

5. Conclusions

This study examined the changes in PM_{2.5} levels as a result of the Covid-19 outbreak. The researchers used data on the levels of PM_{2.5} and other air pollution parameters gathered at 63 points in addition to traffic volume data on 4 expressways from January 2015 to December 2021.

The results showed that during the city lockdown due to the Covid-19 pandemic, the percentage of concentration of the air pollution parameters PM_{2.5} NO_x NO₂ NO and CO, decreased by 14.38, 12.93, 18.43, 2.65, and 5.66%, respectively. In addition, testing the time series air pollution dataset using the Kruskal-Wallis method indicated that the data directly related to seasonal distribution, with the concentrations of pollution being highest during the dry season every year.

In addition, the city lockdown forced people to stay at home and to work and learn online. This directly reduced the

traffic volume by 40%. The average monthly PM_{2.5} level dropped by 21 percent from before the Covid-19 outbreak compared to during the lockdown period. This indicated that during the outbreak, the lockdown had a direct impact on human behavior, particularly transportation, which decreased by 40%. These changes played a substantial role in the reduction of PM_{2.5} concentrations.

While it was not possible to clearly determine which factors (traffic or seasonal) had the greater impact on the PM_{2.5} concentration, the current research provided evidence that human activities, specifically traffic in urban regions, had a notable effect on PM_{2.5} levels.

The PM_{2.5} problem has been of concern in Thailand, with government and academic studies attributing the main cause of increased PM_{2.5} levels to traffic. The current research results showed that decreasing the traffic volume significantly reduced PM_{2.5} levels. The authors believe that this research can contribute to policy

and stake-holder reviews on how to sustainably solve the PM_{2.5} problem in Thailand in a more appropriate way. However, the data collected represent only a sample from a part of Thailand.

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