Engineering and Applied Science Research 2023;50(2):137-148 Research Article

Engineering and Applied Science Research

https://www.tci-thaijo.org/index.php/easr/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

Study the change in air pollution after the COVID-19 outbreak in Thailand

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Received 1 December 2022
Revised 27 February 2023
Accepted 7 March 2023

Abstract

In Thailand, the outbreak of COVID-19 occurred, resulting in a lifestyle change, which could affect the sources of air pollution. This study aims to examine the trend of air pollution changes during COVID-19 in Thailand by air quality measurement data from the ground and satellites, as well as the effect of the traffic volume. From the results, during the normal period, CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$ from the ground station tended to be consistently high (+6.58–56.60%), while satellite data showed that only CO, NO_2 and SO_2 were likely to be higher (+1.20–29.29%). When entering the first lockdown period, the ground data began to tend to decrease, including NO_2 (-10.22%). For the satellite values, there was a similar downward trend, except for the AOD and O_3 (+0.94 and +0.79%). For the 'new normal' period, all parameters of ground data tended to be consistently lower, as well as that of satellites. Furthermore, as a result of the traffic volume that affected the change in air pollutants, during the first lockdown, CO, NO_2, PM_{10} and $PM_{2.5}$, tended to decrease in line with the decrease in traffic. However, during the COVID-19 crisis, it was still found that air pollution remained high, because of the summer (March–May) and from the activities on weekdays. Also, in the correlation of ground and satellite measurements, it was found that the only high correlations in the data were the NO_2 data (r = 0.74), and the correlations were not high for $PM_{2.5}$ (r = 0.54), PM_{10} (r = 0.45), SO_2 (r = 0.30), or CO (r = 0.12), and the lowest was O_3 (r = -0.40). The values from both stations were different, because there may be other factors involved. The relevant information on dependent variables and variables affecting the measurements should also be included to make the forecast more accurate.

Keywords: Air pollution, Satellite, Thailand, Traffic-volume, Number of people travel, COVID-19

1. Introduction

Coronavirus disease 2019 (COVID-19) is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1], that was identified in Wuhan, China on December 31, 2019. Afterward, COVID-19 rapidly spread from China to all over the world and was declared a pandemic by the World Health Organization (WHO) on March 11, 2020. The lockdown measures and social distancing were used as a pandemic action plan to prevent the spreading of COVID-19 [2]. These COVID-19 lockdown measures decreased human activities, especially in the traffic, industrial, and energy production sectors, which assumes a corresponding decrease in anthropogenic emissions of air pollution [3]. Air pollution poses a significant threat to the environment, quality of life, and health impacts [4]. The impact of the COVID-19 pandemic on four major mental health issues of the general Bangladeshi people was investigated, and it was found that the prevalence rates of loneliness, depression, anxiety and sleep disturbance were 71, 38, 64, and 73%, respectively [5]. Currently, many research studies on air quality due to the effects of the COVID-19 outbreak have been reported.

For example, in an analysis based on collective and individual assessments of eight countries present in the region: Pakistan, India, Afghanistan, Sri Lanka, Maldives, Bhutan, Bangladesh, and Bhutan, a 21.10% reduction in the concentration of NO_2 pollutants was identified before the lockdown period (1 February–20 March 2020) compared to the lockdown period (21 March–10 May 2020) [6]. In addition to the COVID-19 lockdown reducing economic activity, especially in the transportation, industrial, and energy production sectors, which in turn implies a decrease in anthropogenic emissions of greenhouse gases and other air pollutants such as O_3, NO_x, CO, SO_2, and aerosols, there were reductions in the average concentrations of atmospheric $PM_{2.5}$ (–30.1%), PM_{10} (–40.5%), SO_2 (–33.4%), CO (–27.9) and NO_2 (–61.4%) during the COVID-19 outbreak in central China during February 2020 [7]. Additionally, there were decreasing trends of NO_2 (27–30%) as well as PM_{10} (26–31%), $PM_{2.5}$ (23–32%), NO_2 (63–64%), SO_2, (9–20%) and CO (25–31%) concentrations in Southeast Asian cities such as Manila, Kuala Lumpur, and Singapore [8]. This study shows that decreased human activities in the industrial and transport sectors had a direct impact [9].

The impact of the COVID-19 outbreak on air pollution in Bangkok was investigated in light of low traffic conditions and reduced human activities due to lockdown measures leading to improved air quality in Bangkok. Overall surface $PM_{2.5}$ concentrations presented a significant decreasing trend during the COVID-19 outbreak year (2020) based on two periods: the lockdown and 'new normal' periods (used to refer to changes in human behavior during the pandemic or speculated changes after the pandemic) by –15.79% and –23.34%, respectively, compared to the same periods in baseline years (2017–2019). Meanwhile, the concentrations of O_3 decreased by ~4–7%, and CO by ~8–23%, during the lockdown and 'new normal' periods, respectively. The NO_2 concentrations increased by ~3–26%, and SO_2 decreased by ~41–84%, in all three periods. Satellite data from MODIS AOD and TROPOMI column data were used to explore air pollution in the upper atmosphere. The results indicated that the surface concentrations of NO_2 and SO_2 did not

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doi: 10.14456/easr.2023.15

decrease during the lockdown period because of added pollutants from the long-range transport of these pollutants from the north and eastern regions of Thailand [4]. The research results mentioned above indicated the COVID-19 outbreak also had a significant positive impact on ground-level air pollution. However, there was no effect at the upper level, because people were expected to lead a ‘new normal’ lifestyle (e.g., work from home, study online, shop online), indicating reduced mobility and economic activity [3, 9].

In Thailand, the outbreak of COVID-19 and the lockdown measures that occurred resulted in a lifestyle change to be different from the original. The modifications can affect the source of air pollution directly or indirectly. Therefore, it is important to report on the criteria and amount of air quality each day in each area, so that people can be aware of the dangers and potential consequences that may follow. At present, the Pollution Control Department is an important part of alerting the amount of air quality and can prevent the impact that occurs. In addition, the measurements from the satellite are also important, because they can check the area covered, and the measurements on the atmosphere have credibility. Therefore, the study of changes in air pollution from the ground and satellites is an interesting study to lead to monitoring and assessing the impact of COVID-19. This study has the purpose of investigating the impact of air pollution in the COVID-19 outbreak with measures from air quality ground station and satellite data together with the traffic volume and the number of people traveling in Thailand during 2017–2021 to study the change of air pollutants in Thailand, the trends in traffic volume, and the number of people traveling, which could affect the change in air pollution during the COVID-19 situation.

2. Materials and methods

2.1 Data collection

2.1.1 Study area

Thailand is located in Southeast Asia. Slightly above the equator or between latitude or latitude at 5°37’ N, 20°27’ N and between longitude or latitude at 97°22’ E and, 105°37’ E. It has an area of 513,120 Square kilometers, located in the middle of Southeast Asia adjacent to the Andaman Sea and the Gulf of Thailand. The administrative area can be divided into 77 provinces, as shown in Figure 1.

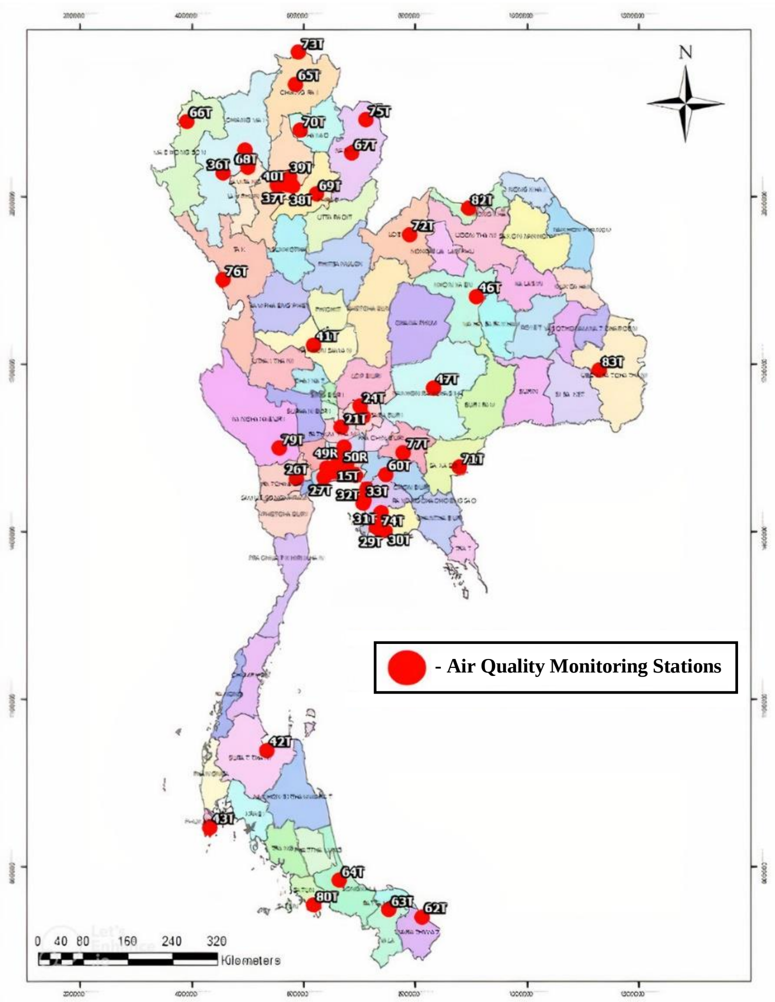

Figure 1 Study Area and ground monitoring station in Thailand.

2.1.2 Ground monitoring data

Air quality monitoring data from 60 stations throughout Thailand support data from the Pollution Control Department (PCD) [10] including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), and particulate matter ($PM_{2.5}$, PM_{10}) from 1 January 2017 to 30 August 2021.

2.1.3 Satellite data

Collected air quality data from satellite air measurement data [10-12] namely Aqua, Terra (Modis, MOPITT Sensor) [13-15], Aura Satellite (OMI Sensor) [16, 17] and European Remote-Sensing Satellite (GOME-2B Sensor) from January 1, 2017 to August 30, 2021 during 9.00-12.00 a.m. and 1.00-3.00 p.m. It can be downloaded from the Nasa and Temis websites www.temis.nl. and https://ladsweb.modaps.eosdis.nasa.gov

2.1.4 Other information

Used traffic volume information from the Department of Highways and Statistical data on all transport from the Ministry of Transport throughout Thailand by collecting data from year 2017–2021.

2.2 Data analysis

We compiled data on air quality measurements and meteorological conditions at the locations and coordinates (latitude and longitude) of 60 ground monitoring stations in Thailand (PCD) from January 1, 2017, to August 30, 2021, into Excel and used ArcGIS [11, 18-20], HDFView-3.0.0 and PanoplyWin, to open the downloaded air quality data from the satellite [10, 21-24] to read the air quality data according to the coordinates (latitude and longitude) by specifying the size of the satellite grid area as in Table 1

Table 1 The size of the grid area of the satellites used in operations.

The air quality	Satellite	Time period	Recording time	Space size grid of satellites (m)
CO	MOPITT, Terra	2017-2021	10.00-11.00 am	0.5º × 0.5º
NO_2	GOME2B, METOP-B	2017-2021	09.30-11.00 am	0.25º × 0.25º
O_3	OMI, Aura	2017-2021	13.00-15.00 pm	0.25º × 0.25º
SO_2	OMI, Aura	2017-2021	13.00-15.00 pm	0.25º × 0.25º
AOD	MODIS, Aqua	2017-2021	13.00-14.00 pm	0.25º × 0.25º
AOD	MODIS, Terra	2017-2021	10.00-11.00 am	0.25º × 0.25º

After collecting the information for the study, the next step was to analyze air quality measurement data with ground and satellite averages. For information from the ground, the times between 09:00–12:00 and 13:00–15:00 were selected to correspond with the time that each type of satellite passed through Thailand, as shown in Table 1. The data analysis process, as shown in Figure 2, and the objects to be studied in detail were as follows.

1. Data were analyzed by specifying the period of the COVID-19 situation as follows:
   (1) the period before the lockdown measures (normal) (January 2017 to February 2020),
   (2) during the first lockdown measures (first lockdown) (25 March to 31 May 2020), and
   (3) during the 'new-normal' (behavior after the lockdown measures), (1 June 2020 to 31 August 2021).
2. The factors affecting the change in air quality, such as traffic volume and the number of people traveling on the transport network were studied.

For the changes in air pollutants as a result and the resulting lockdown measures in COVID-19, the average for each period of the year was calculated with consistent data. Then, the percentage increase was calculated, and the data were reduced by calculating the percentage difference (% change) using a formula in Microsoft Office Excel.

Correlation analysis was used to study the relationship between variables. The main objective of regression analysis is an estimation of a variable, known as a dependent variable, which is commonly denoted by Y based on knowledge from other variables, which is called an independent variable, commonly denoted by X.

The correlation coefficient is measured as a number between -1 and 1. If r is close to 1, the two variables are highly correlated and have the same direction. If r is a value close to -1 indicates that the two variables are also highly correlated but opposite in direction, as in equation (1).

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}} \quad (1)$$

Where X is the value of the variable X.
Y is the value of the variable Y.
n is the number of samples.

Then the results of the comparison of the changing trends of the various data were summarized to determine future trends and changes in atmospheric air pollution. The analyzed data were then presented in graph format, which is a report on air quality that is easy to understand for the public. The advantage of the technique used by the researchers is that it is a simple technique. Anyone can learn and can easily understand the analysis results, and trend comparison gives readers the advantages of ground data. It is a measurement with high reliability. Because the measurement point is close to the pollution source and can be monitored in real time, and the limitations due to ground and satellite measurements, various factors are different, causing discrepancies in the analysis of the data to occur.

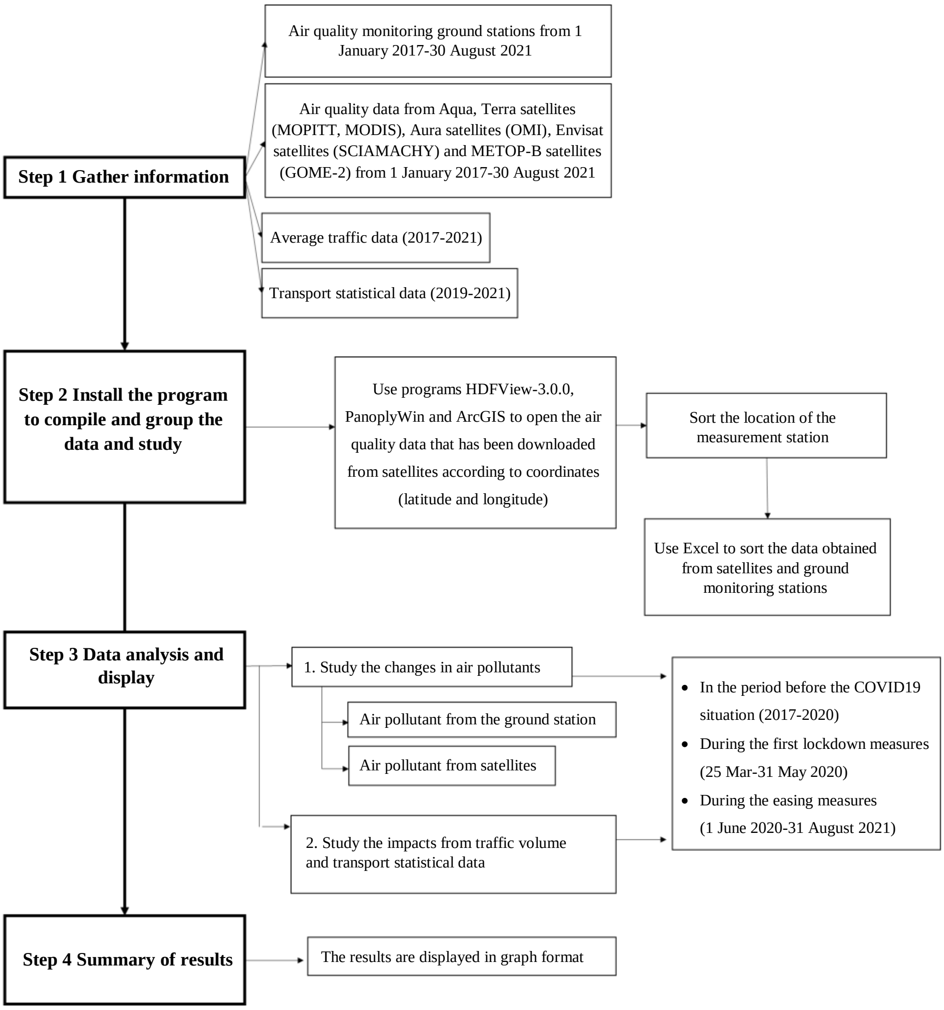

Figure 2 Procedures and methods.

3. Results

3.1 Changes in air pollutants in during COVID-19 years 2017-2021

This part of the study started at the beginning of the COVID-19 period until August 31, 2021, which was the end of the data collection and analysis. From the data collection, the first COVID-19 outbreak occurred on January 20, 2020, and the first lockdown measures began on March 25, 2020, followed by the announcement of the relaxation of the lockdown measures on xx. Even though the number of infected people started to decrease on June 1, 2020, there were still measures. Then, the second outbreak occurred on December 17, 2020, and the third one occurred on April 4, 2021, respectively. The study results are shown in Figure 3 (a-f).

From the study, air pollutants measured from the ground, comprising CO, NO_2, SO_2, PM_{10}, and $PM_{2.5}$, tended to be high during the corresponding 'normal' (winter) period of 2017–2021, except for the amount of O_3 that was found during the first lockdown of 2019 (March–May), which was during summer. The warmer the air, the higher the amount of O_3 in the atmosphere. The tendency of the change in the O_3 concentration was related to the photochemical reactions between primary gases, such as CO, SO_2, NO_2, and VOCs that converted to O_3 and secondary aerosols [25]. As such, the study was consistent with the results [26] of increased air pollution concentrations in the early part of the COVID-19 period due to the changing of the seasons from winter to summer. During the summer season, a higher amount of UV radiation reached the earth, and it can become a critical component in stopping coronavirus transmission. [27] Moreover, there was low humidity and wind speed due to the reduced influence of the monsoon. Every parameter had a consistent decline every year during the new normal (June–August) due to the rainy season. It was also found that the normal period of 2021 tended to be higher than the previous year, except for the part that the particulate matter tended to be lower in 2020, with $PM_{2.5}$ and PM_{10} being the lowest during the first lockdown. Furthermore, in the case [3], the CO and NO_2 concentrations showed significant reductions similar to those originating from automobiles, power plants, and combustion activity. The CO concentrations, based on the study, revealed the significant effect of the lockdown measures.

While the measurements from the satellite showed that the amount of CO, NO_2, and SO_2 tended to be high during the normal period of every year (January-March) because the weather at that time was winter, SO_2 was found to be the highest during the new normal even during the rainy season. This trend conflicted with other parameters, and in part, the AOD values from the Aqua and Terra sensors were high during the first lockdown. In contrast, the lowest trend was during the new normal or during the rainy season. In the overview of the satellite values, it could be seen that CO, NO_2, SO_2, and AOD were likely to decline from 2020 to 2021, which was in line with the COVID-19 period, except for O_3 that tended to increase in the same way as the data from the ground. This was consistent with the results of [28] that found that O_3 concentrations fluctuated more than in 2019, with rising and falling patterns in the normal and lockdown periods. Additionally, there was a downward trend during the new normal, particularly during the first lockdown, where the O_3 concentrations tended to correspond to the $PM_{2.5}$ concentrations.

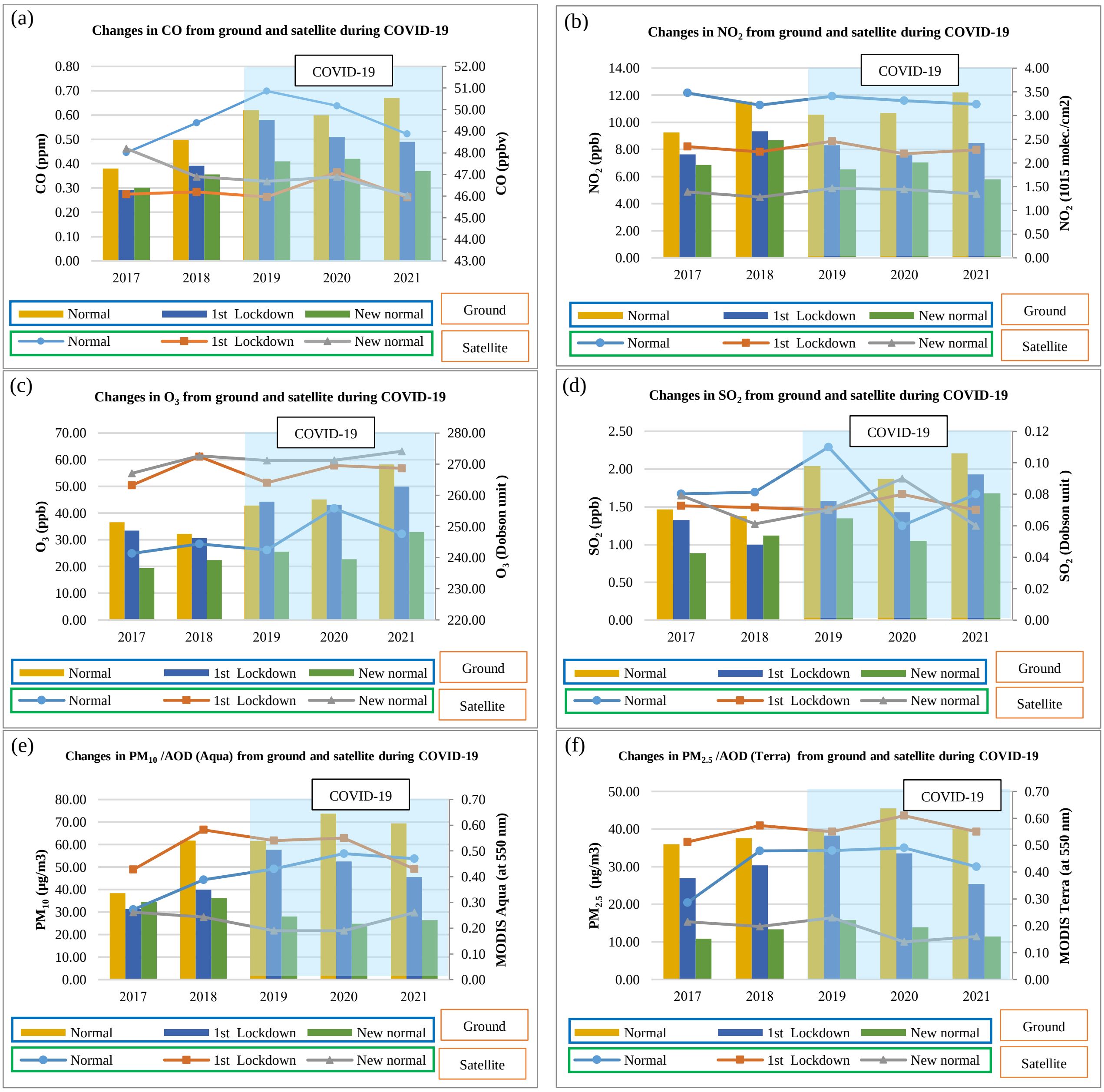

Figure 3 Trend of changes in air quality measurement data from the ground station and satellite during COVID-19 (2017-2021) (a-f).

Table 2 shows the changes in air emissions between the ground and satellite representing the average for the period of 2017-2019 (base year) compared to 2020 and 2021, which was the study's COVID-19 situation. It was found that the change in CO from the ground had a tendency to increase in all three phases of 2020 and 2021, while CO from the satellite occurred during the new normal in 2020 and in all three phases in 2021. From the table, there was a strong conflict of information. As for the amount of O_3, it was found that both the ground and satellite were likely to increase in 2020 and 2021, thus corresponding to the three periods of COVID-19. The results of NO_2 and SO_2 could display the changing trends in the same way from the data from the ground that had a downward trend during the new normal of 2020 and 2021, when compared with the satellite data. From the significantly decreasing trends in all three phases of COVID-19 in 2021, and for the changes in fine particulate matter (PM_{10} and $PM_{2.5}$) and satellite AOD values, it could be seen that both sources displayed a trend in the same direction. As such, there would be a tendency to show a decrease on the ground. In addition, the most visible satellites were the new normal for 2020 and 2021, while the normal period included the first lockdown, where there was a marked increase in PM_{10} and AOD from the Terra sensor. Most of the measurements from the ground still had an increasing trend. This was even in the range of COVID-19, except for the NO_2 and PM_{10} values that tended to decline during the new normal, therefore indicating that the reduction of public travel during the lockdown period resulted in the amount of NO_2 and PM_{10} generated from the source. Likewise, depending on the origin of the vehicle, there was a decrease accordingly. As for the measurements from the satellites, it was found that the portion was likely to decline in 2021, except for O_3, which had a higher trend in line with the ground because this was summer. This was consistent with the study, where the average daily concentration of O_3 increased significantly in city stations; for example, 14% in Rome, 24% in Nice, 2.4% in Valencia, 27% in Turin, and 36% in Wuhan during the lockdown in 2020 [28]. The ESA collects air quality data by using satellite instruments during COVID-19 lockdowns and there were noticeable results (i.e., 70% and 20–30% NO_2 reduction in India and China, respectively) [29].

Table 1 Percent Change of Air pollution in Thailand (Avg. 2017-2019)/ 2020 and 2021

From ground station	% change (Avg. 2017-2019)/ 2020	% change (Avg. 2017-2019)/ 2021	From satellite	% change (Avg. 2017-2019)/ 2020	% change (Avg. 2017-2019)/ 2021
CO (ppm)			**CO (ppbv)**		
Normal	+20.18	+34.20	Normal	+1.54	-1.11
First lockdown	+21.13	+16.38	First lockdown	+2.24	-0.28
New normal	+18.21	+4.14	New normal	-0.79	-2.61
NO_2 (ppb)			**NO_2 (10^{15} molec./cm^2)**		
Normal	+2.21	+16.75	Normal	-1.69	-3.97
First lockdown	-10.22	+0.58	First lockdown	-6.47	-3.13
New normal	-4.26	-21.13	New normal	+4.74	-2.11
O_3 (ppb)			**O_3 (Dobson unit)**		
Normal	+21.35	+56.60	Normal	+5.39	+2.03
First lockdown	+19.17	+37.88	First lockdown	+1.11	+0.79
New normal	+1.29	+46.77	New normal	+0.34	+1.42
SO_2 (ppb)			**SO_2 (Dobson unit)**		
Normal	+14.80	+35.67	Normal	-33.74	-11.66
1st Lockdown	+9.86	+48.28	First lockdown	+11.99	-2.01
New normal	-6.17	+50.13	New normal	+28.39	-14.41
PM_{10} (µg/m^3)			**MODIS Aqua (at 550 nm)**		
Normal	+36.66	+28.60	Normal	+34.79	+29.29
First lockdown	+22.04	+6.11	First lockdown	+6.47	-16.76
New normal	-24.65	-19.99	New normal	-18.07	+12.12
$PM_{2.5}$ (µg/m^3)			**MODIS Terra (at 550 nm)**		
Normal	+20.90	+6.58	Normal	+18.07	+1.20
First lockdown	+5.32	-20.20	First lockdown	+11.95	+0.94
New normal	+3.74	-14.38	New normal	-34.65	-25.32

Note + xx is a percentage increase, - xx is a percentage decrease.

3.2 Calibration of changes in air pollutants from ground and satellites (2019-2021)

From Figure 4, the relationship between air pollutants from ground and satellite data was studied by calculating the correlation coefficient (r) to compare the relationship between the data from both sources. The correlation of measurement data from ground and satellite shows that the correlation data at a high level was NO_2 data (r = 0.74), the moderate level was $PM_{2.5}$ (r = 0.54), the low level was PM_{10} (r = 0.45) and very low levels were SO_2 (r = 0.30), CO (r = 0.12) and O_3 (r = -0.40) respectively. The changes in NO_2 concentrations from the ground and satellites were the most consistent, while the other parameters changed to a lesser extent. This is the same as the results of [18, 19], suggesting that integrating OMI-based and ground-based measurements can provide valuable data to study spatial distribution and temporal variability in NO_2 levels. For the values measured from the ground, there was a difference with those obtained by satellite, because there may be other factors involved such as the altitude at which the satellites took measurements, measurement time, the number of clouds that cover the atmosphere and the climatic conditions while measuring. All of these have resulted in both the ground and satellite measurements having high tolerances. For accuracy, satellite data should only be used during cloud-free weather. In general, the satellite will pass over Thailand every 1-2 days, but not cover a nationwide area, causing the information collected to be incomplete. Meanwhile, the ground measurement point, if placed too close to the source, will result in the measured data values being greater than they should be. The relevant information on dependent variables and variables affecting the measurements should also be included to make the forecast more accurate. Therefore, satellite data is important for real-time air quality reporting as a whole and can be used as calibration data for the accuracy of the data obtained on the ground. There is a high degree of discrepancy or its application to the model. The study should bring information on various variables related to and affect the measurements such as meteorology and the number of clouds with the technique to be included to make the forecast more accurate. If the amount of data used in the study is small, the accuracy of the forecast will also decrease.

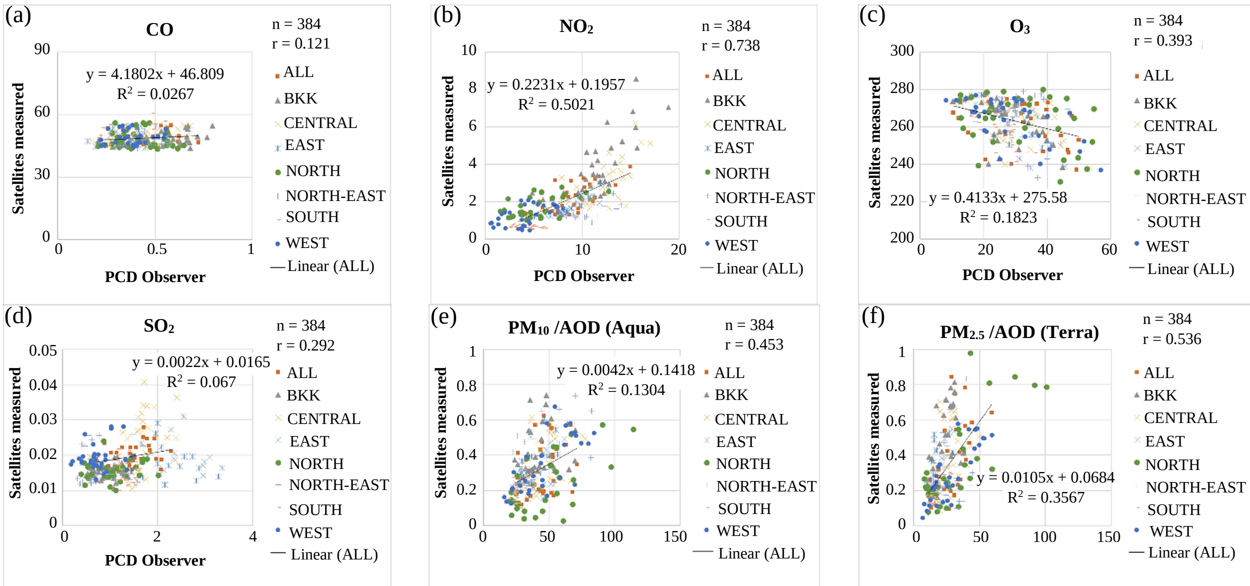

Figure 4 Relationship of ground and satellite air pollutants data during the COVID-19 (a-f).

3.3 The study of pollution source factors affecting air pollution (during COVID-19)

3.3.1 Traffic volume factors during COVID-19

From Figure 5 (a), it was found that the traffic volume was highest in the central region and next is Bangkok tendency to increase in 2017-2019 and decrease in 2020, when it entered the period of COVID-19 and lockdown. Except in the central region and the western region, which tends to increase from 2019, which is 2021 the traffic volume continues to decline in all regions. The downward trend in 2021 is due to the end of 2021 data collection that did not complete the year. As a result, the amount of data analyzed tends to drop considerably.

3.3.2 Travel factors according to various forms during COVID-19

From Figure 5 (b), the results of the data trend analysis showed that the number of people classified by travel style during 2019 and 2020-2021 differed greatly. This was because of the decreasing trend in the number of people traveling due to COVID-19 and the government's announcement of lockdown measures throughout the year. During the first lockdown in 2020 (March to May), the trend of all forms of travel was noticeably reduced, especially by road. The number of people traveling by road was reduced from 63,463,731 people in 2019 to only 1,050,461 people in 2020, followed by rail from 36,186,943 people in 2019 to only 863,041 people in 2020. Then, when people returned after the new normal in June 2020 onwards, the number of people who started returning to travel began to show a tendency of an increase. However, in 2021, there was a decrease again, which was due to the second outbreak in December 2020, that continued until the third outbreak in April 2021. As a consequence, the change in air pollutants and the number of people traveling in 2019 and 2020-2021 was affected by COVID-19 and the lockdowns.

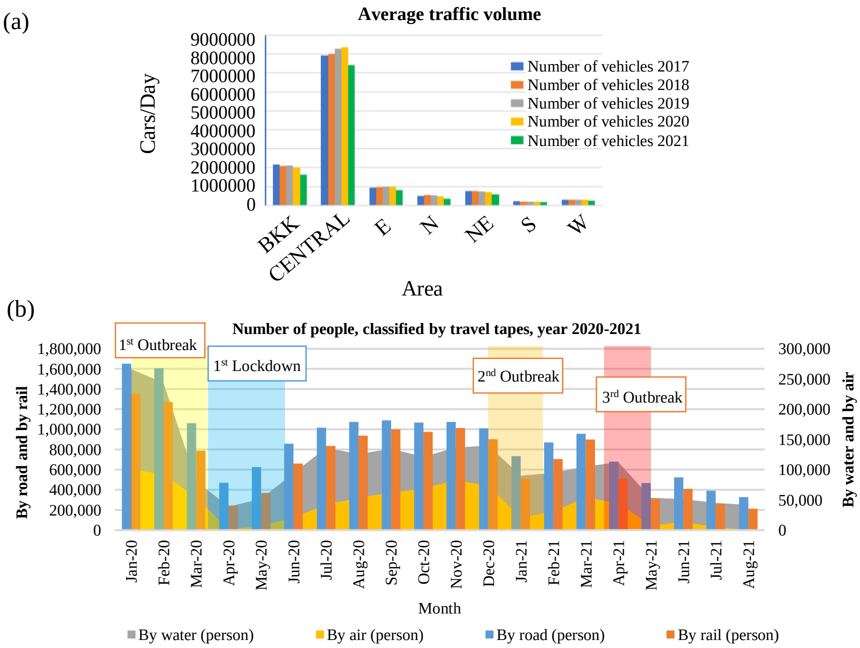

Figure 5 (a) Average traffic volume, (b) Number of people classified by travel types in 2020-2021.

Figure 6 (a-f) shows the change in air pollutants. From the comparison of the volume of private cars entering and exiting the Bangkok area and the number of people traveling in 2019 and 2020-2021, it was found that during the first lockdown period (from March 25, 2020), the trend of the decrease in air pollutants corresponded to the decrease in the number of automobiles. Furthermore, the number of people traveling clearly showed which factors affected the change of air pollutants. It was found that in 2019, the change in air pollution occurred according to the natural weather conditions, such as during the dry season, the PM_{10} and $PM_{2.5}$ values tended to be higher than during the rainy season [11] and when observing the trends in 2020-2021, even during COVID-19, the number of travelers had reduced. Nonetheless, in March 2020, during the dry season, the dry, hot weather and the accumulation of dust was caused by combustion that also tended to be high according to the weather conditions. Although this was slightly lower than in 2019, as stated in the study by [9], the range of the highest $PM_{2.5}$ concentrations was found to be significantly correlated with the open combustion of biomass Household Burning and Traffic Index. In addition to the weather that was the main factor of the traffic volume, the number of people traveling had decreased due to the lack of activities during the lockdown period. This showed the effect on the change, and the air pollutants would rise again after the announcement of easing the measures on June 1, 2020. Then, in the second outbreak (December 20, 2020) and third outbreak (April 4, 2021), similar changes would be evident as in the first outbreak.

In addition, the amounts of CO, SO_2, NO_2, PM_{10}, and $PM_{2.5}$ generated from the vehicle origin showed a tendency to decrease with the traffic volume, and the number of people traveling during the lockdown period, clearly corresponding with certain days, showed that significant reductions in NO_2 corresponded to traffic volumes [30], while O_3 tended to be higher than the other parameters before trending downward when entering the rainy season.

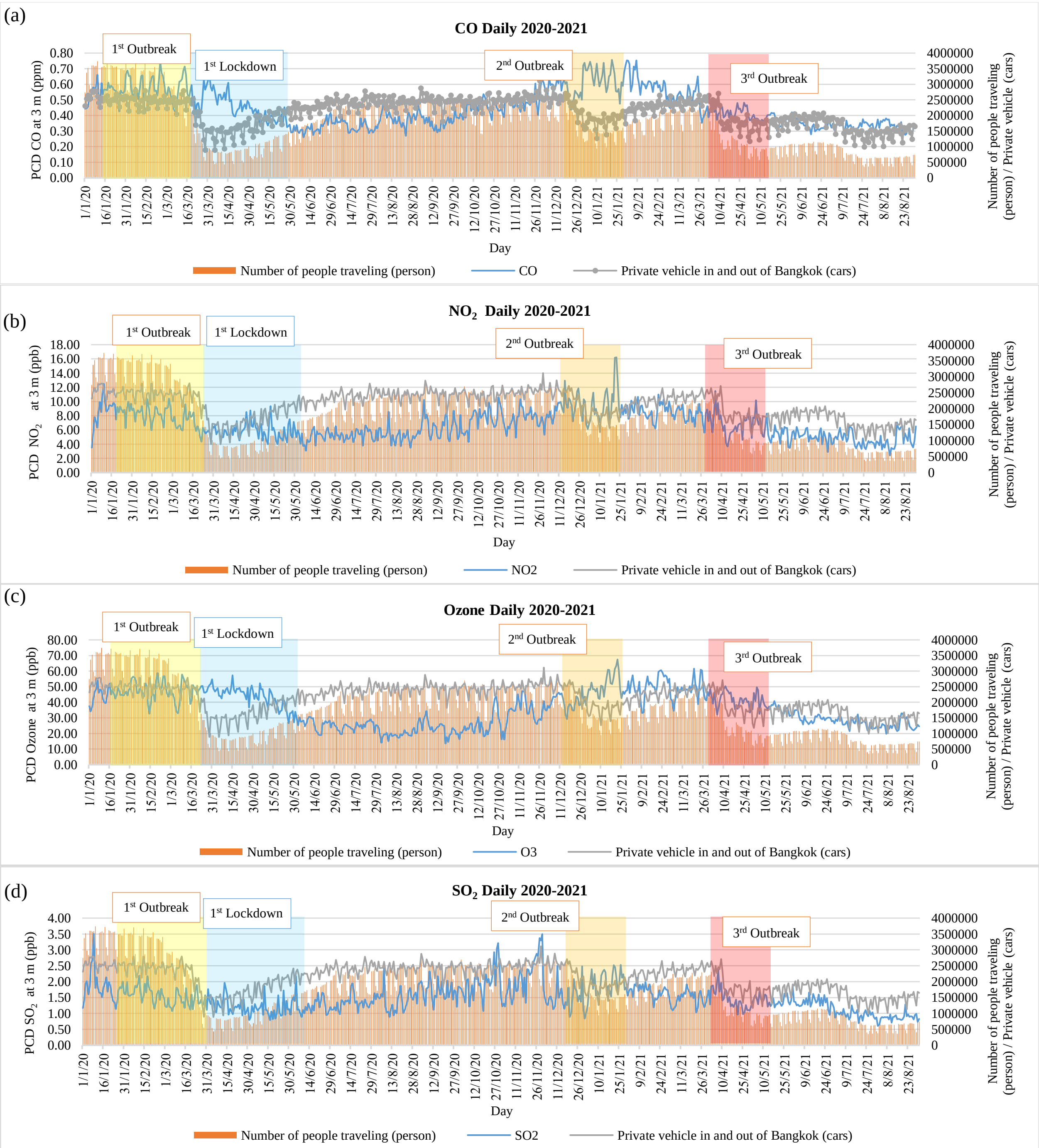

Figure 6 Changes in air pollutants compared to the volume of private cars and the number of people traveling (a-f).

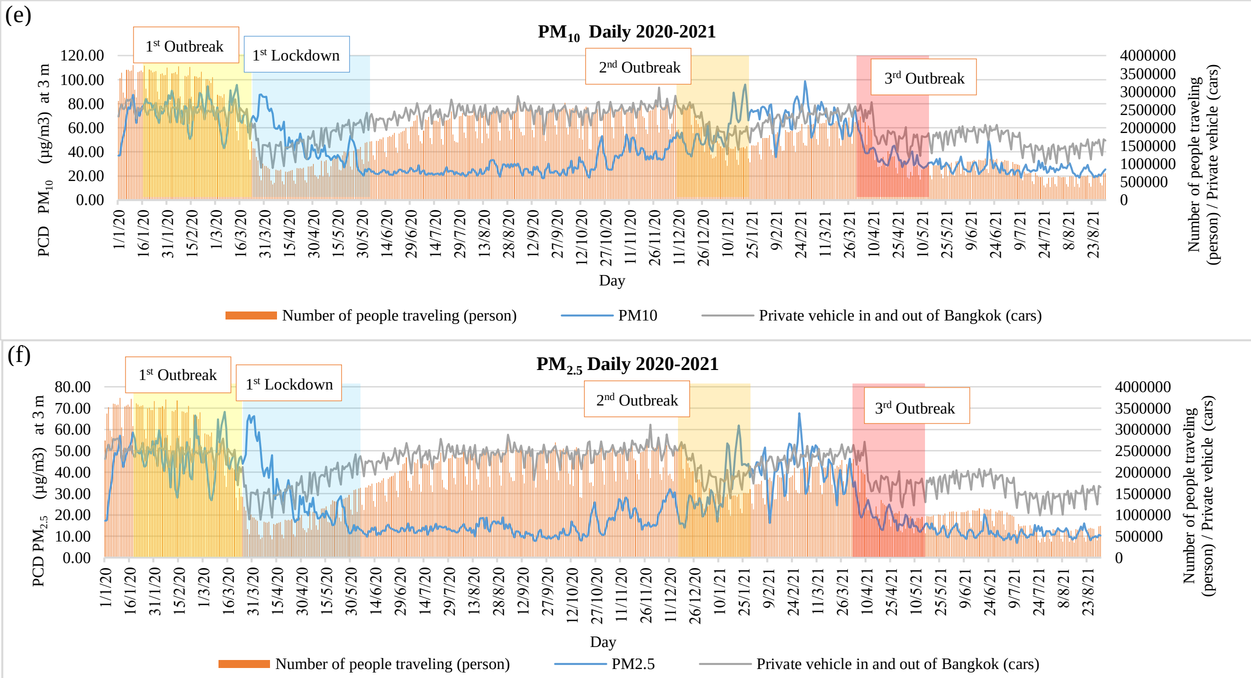

Figure 6 (continued) Changes in air pollutants compared to the volume of private cars and the number of people traveling (a-f).

From Figure 7, the analysis of the air pollutants shows the comparison of the number of cars and the number of people traveling during COVID-19 and the first lockdown measures (between March 15 to June 1, 2020). This compared Monday-Friday (weekdays) or days when people went to work and Saturday-Sunday (weekend). As a result of the study, even during the lockdown period, some people still left home for work. From the graph comparing the weekdays with holidays, it was found that during the holidays, there would be some traffic volume and a number of people traveling. Moreover, the amount of air pollutants decreased during the weekdays, except the O_3 values that were not different from the weekdays. As for the long weekend (May 1-3), there were similar changes to a normal holiday. Additionally, when announcing the relaxation of the situation (June 1), from the graph, the traffic volumes and the number of people traveling more than in the past could be seen in terms of air pollutants that tended not to change much, which was caused by being the period entering the rainy season.

The results show that most of the parameters were the main sources of pollutants from the combustion of engine fuels are CO, NO_2, $PM_{2.5}$ and PM_{10}, which are consistent with the results of a study by [31] that the amounts of air pollutants in the preceding year of the COVID-19 outbreak changed $PM_{2.5}$ concentrations, with a decline in April. Because of a holiday (the Songkran Festival), many people travel from Bangkok to provincial regions. As a result, the traffic volume is low and the amount of $PM_{2.5}$ is less concentrated in Bangkok. Meanwhile, during the COVID-19 lockdown in 2020, interprovincial transport was regulated, and the Songkran holiday was postponed due to lockdown measures. The amount of traffic and working hours in Bangkok remained the same in the study [30].

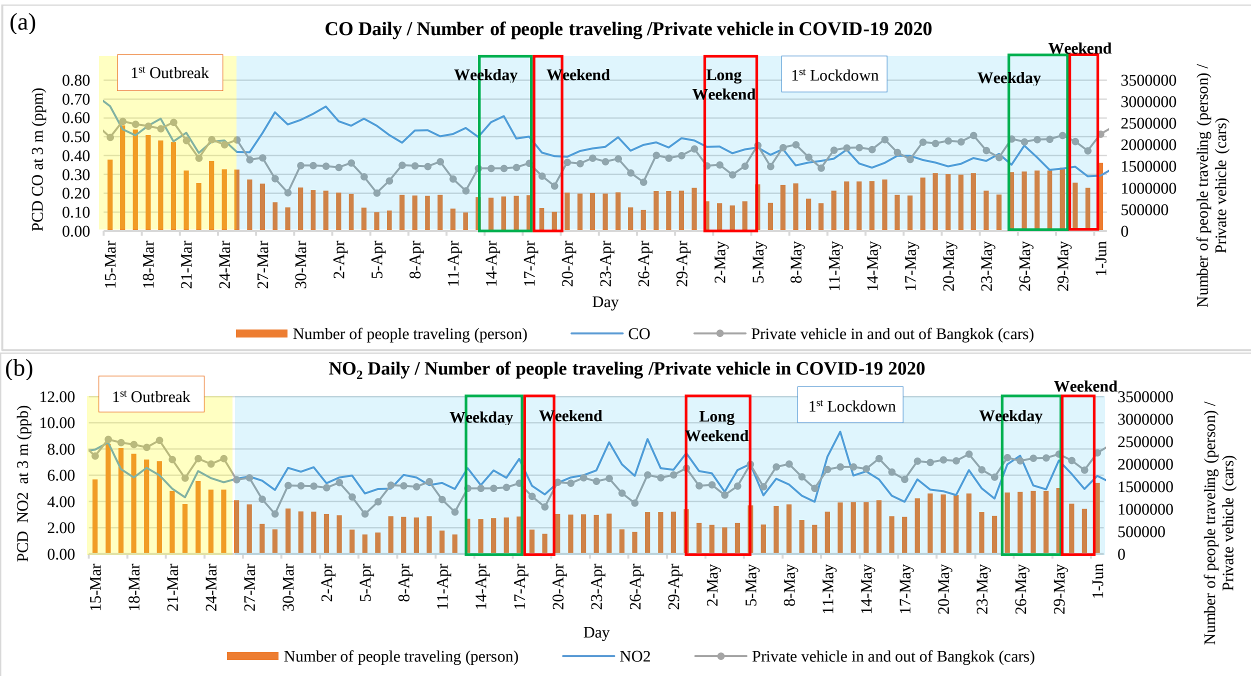

Figure 7 Air pollutants compared to the volume of private cars and the number of people traveling during COVID-19 (a-f).

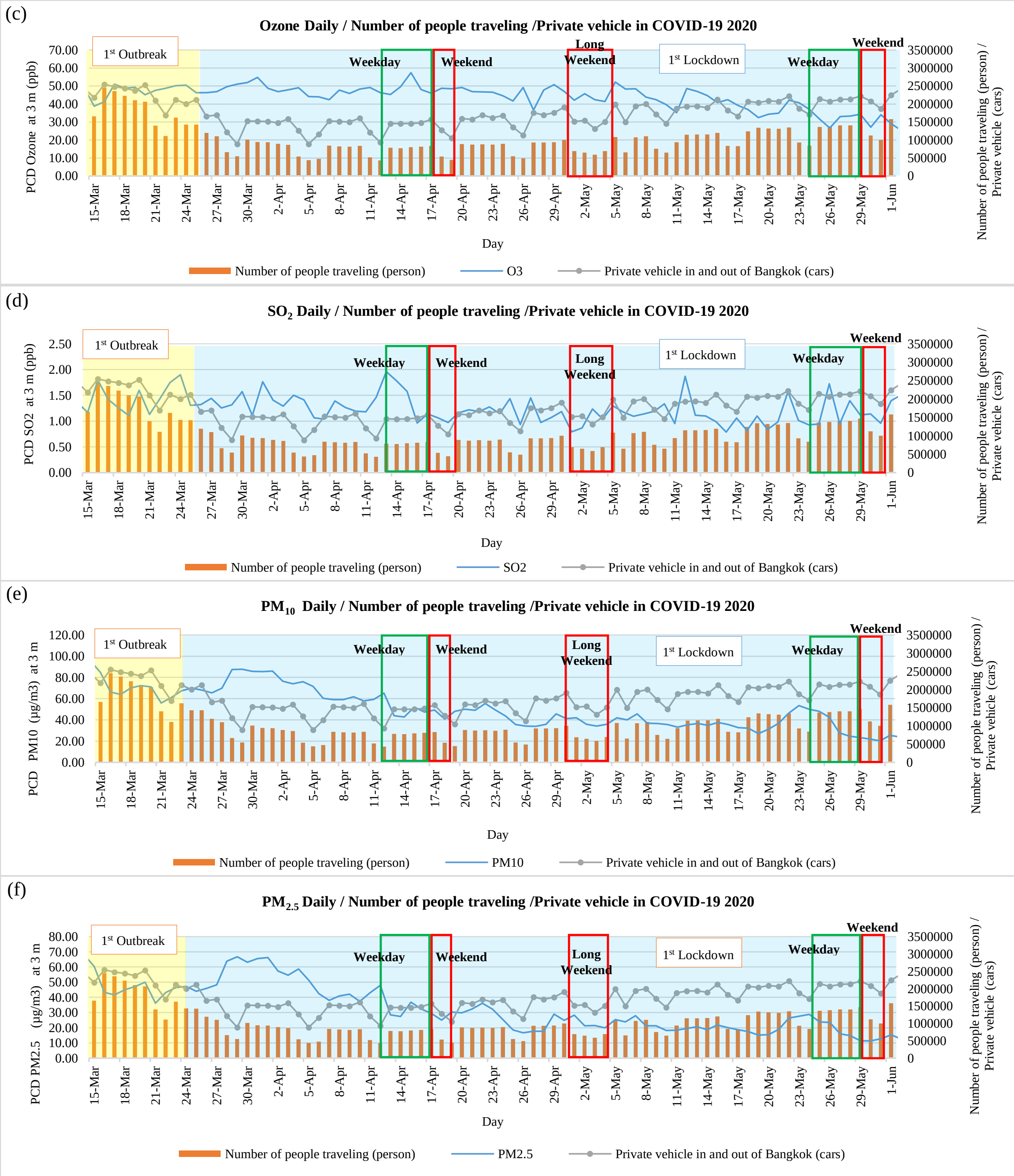

Figure 7 (continued) Air pollutants compared to the volume of private cars and the number of people traveling during COVID-19 (a-f).

4. Discussion

The results of this study can be summarized as to the trend of traffic volume and the number of people traveling that affects the change in air pollution during COVID-19. When comparing the number of private cars entering and exiting Bangkok and the number of people traveling during COVID-19, it was found that during the 1st lockdown, air pollutants from vehicle sources, namely CO, NO_2, PM_{10} and $PM_{2.5}$, tended to decrease. This lower air pollution corresponds to a decrease in the number of cars and the number of people traveling resulting from the lockdown measures, whereas O_3 was still trending upward. These results thus clearly show the impact of the change, and although the number of travelers decreased due to the COVID-19 situation, it was still found that air pollution continued to be high due to weather conditions, because it was summer (March-May). In addition, the amount of air pollutants increased again after the announcement of the relaxation of the New Normal measures.

The impact of COVID-19 on the amount of air quality in each region is evident, including Bangkok, the central, northern and northeastern regions. Because Bangkok is an area where many people live, COVID-19 occurrence and protective measures were the factors that most noticeably affected the change in air quality during COVID-19. Meanwhile, in the central, northern and northeastern regions, the impacts and changes from COVID-19 were less than those from climate change. Furthermore, in the western, southern and eastern regions, there was a change in air quality from COVID-19 at a lower level than in other regions.

Meteorological data in each region is an important factor that causes differences in climate change trends due to the temperature in the northern region, and the Northeast is the area where the weather is in winter and the influence of high-pressure mass from China, causing dust in the northern region to be unable to float up high and be spreadable. As a result, the accumulated amount is high [16], while in the South it is found that the change in air quality tended to change less. Because the South is a hot and humid area, the rainy season is longer than in other regions. The amount of rainfall is therefore a factor that dilutes the concentrations of the parameters. In Bangkok, most of the changes in air quality were due to the imposition of lockdown measures; reducing travel is therefore an important factor in the reduction of air pollutants from various sources. In this study, $PM_{2.5}$ concentrations were decreased during the lockdown period by 25–58%, and NO_2 concentrations were reduced in 2020 by 12–91%. Furthermore, the variations in meteorological parameters remained similar during the lockdown and in the corresponding periods in previous years. [31]

5. Conclusions

This research used data to measure air quality from the ground station and satellites with traffic volume and the number of people traveling to compare trends of air pollutants occurring throughout Thailand during the COVID-19 epidemic situation. From the results, during the normal period, the air pollutants measured from the ground, such as CO, NO_2, SO_2, PM_{10} and $PM_{2.5}$, tended to be consistently high in 2017–2019 and increased even higher in 2021, except for small particulate matter, which tended to decrease from 2020 until 2021. Meanwhile, satellite data showed that only CO, NO_2 and SO_2 were likely to be higher than for other periods in 2017–2021. When entering the first lockdown period, the data from the ground began to tend to decrease, including NO_2 and especially $PM_{2.5}$, which were lower than in other periods as a result of the reduction of traffic. In terms of the satellite values, there was a similar downward trend, except for the AOD and O_3, which tended to be higher than the normal period. Also, when entering the ‘new normal’ period, all parameters of ground data tended to be consistently lower from 2017–2021, similar to the values from the satellites. For the relationship of the ground and satellite measurements, the highest correlating data were for NO_2 (r = 0.74), the medium correlating data were for $PM_{2.5}$ (r = 0.54), the low correlating data were for PM_{10} (r = 0.45), and the very low correlating data were for SO_2 (r = 0.30), CO (r = 0.12) and O_3 (r = -0.40), respectively. For the values measured from the ground, there was a difference from those obtained by satellite, because there may be other factors involved, such as the altitude at which the satellites took measurements, measurement time, the number of clouds that covered the atmosphere and the climatic conditions while measuring. All of these resulted in both the ground and satellite measurements having high tolerances. The relevant information on dependent variables and variables affecting the measurements should also be included to make the forecast more accurate. From the study of the traffic volume trends and the number of people traveling that affected the change in air pollutants during COVID-19, it was found that during the beginning of the first lockdown, air pollutants caused by vehicle sources, which were CO, NO_2, PM_{10} and $PM_{2.5}$, tended to decrease in line with the decrease of traffic, whereas O_3 was to trend upward. Although the traffic volume decreased due to the COVID-19 crisis, it was still found that air pollution remained high, because of the summer (March–May) and from the activities on weekdays. In addition, the ‘new normal’ and the announcement of a relaxation of the measures resulted in increased air pollution. From the results, the impacts causing the reductions in air pollution can be seen.

The results of this research study could be applied to the development of future air quality education and online alerts, as well as be able to use and analyze the results together with other data, and studying air pollution during COVID-19 could continue to be assessed. Furthermore, this data could be used to set guidelines and measures to reduce environmental pollution to match the changing world. However, with the elimination of ground inspection stations in Thailand that were not thorough and could not cover all areas, this would make using satellite data an appropriate option to improve future forecasts and air quality alerts.

6. Acknowledgements

Thanks to the Pollution Control Department of the information and related agencies. Satellite data is available through The National Aeronautics and Space Administration (NASA) and Tropospheric Emission Monitoring Internet Service (TEMIS) project website. Traffic volume information from the Department of Highways and statistical data on the all transport network from the Ministry of Transport. That provided information as well made this study successful.

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