



# Relationship Between COVID-19-Infected Number and PM<sub>2.5</sub> Level in Ambient Air of Bangkok, Thailand

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## Abstract

Several empirical studies of reductions in air pollutants as social distancing and working from home (WFH) policies have sparked recommendations that the COVID-19 pandemic might have been responsible for better air quality particularly in urban area. These findings offer a compelling provocation for the scientific community to detect and investigate variations to air quality as a consequence of government enforced quarantine. In spite of countless research studies focusing on the connection between WFH policy and air pollutant levels, the majority of discussion has unfortunately ignored the central role of other potential sources (e.g. agricultural waste burnings, cooking emissions, and industrial releases) in governing air quality, or has neglected the psychological and social impacts of COVID-19. In this study, a *t* test was used to compare the average concentrations of PM<sub>2.5</sub> and COVID-19-infected numbers (*n*) in three different periods which were  $n < 300$  vs.  $n \geq 300$ ,  $n < 500$  vs.  $n \geq 500$ , and  $n < 700$  vs.  $n \geq 700$ . Some significant differences were observed in the groups of  $n < 500$  vs.  $n \geq 500$ , and  $n < 700$  vs.  $n \geq 700$  indicating that the psychological and social impacts play a crucial role in restricting daily activities and thus reducing the atmospheric contents of PM<sub>2.5</sub> in some areas. Further assessments were conducted by separating PM<sub>2.5</sub> contents into three different periods (i.e. Period-I: day-1 ~ day-10; Period-II: day-11 ~ day-20; Period-III: day-21 ~ day-31). Some significant reductions of PM<sub>2.5</sub> during the Period-I were detected in the eastern area of Bangkok. In addition, Pearson correlation analysis showed that hot-spot numbers appear to be a minor of importance in controlling PM<sub>2.5</sub> levels in the ambient air of Bangkok, Thailand.

**Keywords** PM<sub>2.5</sub> · Working from home (WFH) · Bangkok metropolitan administration (BMA) · Hot spot · COVID-19

## 1 Introduction

Since the World Health Organization (WHO) formally announced the SARS-CoV-2 as a global pandemic on March 11, 2020, there have been 110,224,709 confirmed cases of COVID-19, including 2,441,901 deaths on February 20,

2021. Without any doubts, COVID-19 pandemic has dramatic impact on numerous dimensions such as economic shock, logistics, supply chain, tourism industry, education, mental health, agriculture, food security, and animal sectors (Basilaia and Kvavadze 2020; Gagliano et al. 2020; Grida et al. 2020; McKibbin and Fernando 2020; Proaño 2020; Sahu 2020; Seleiman et al. 2020; Williams 2021). Apart from the above-mentioned impacts, a work from home policy has been widely adopted as a part of government enforced quarantine measures to reduce the outbreak of pandemic (Purwanto et al. 2020; Setyawan and Lestari 2020). As a consequence of a transition to remote working amid COVID-19 pandemic, numerous studies have been focused on the improvement of air quality level particularly in urban area around the world (Lian et al. 2020; Mahato et al. 2020; Stratoulis and Nuthammachot 2020).

Although there have been many studies focus on the chemical characterization of air pollutants in the ambient air of Thailand, little is known about the impact of lockdown

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policy on the improvement of air quality (ChooChuay et al. 2020a, b, c; Pongpiachan and Iijima 2016; Pongpiachan et al. 2013, 2017). Several investigations have been conducted to elucidate the relationship between the “COVID-19 lockdown” and “air pollutant levels” in the ambient air of Thailand (Oo et al. 2021; Wetchayont 2021). A significant reduction of NO<sub>2</sub> level up to 20.1% was observed in the Bangkok Metropolitan Area (BMA) during the government enforced quarantine in 2020 (Oo et al. 2021). The monthly average of NO<sub>2</sub> in BMA observed in 2020 was also 9.8% lower than 2019 for the same time duration (Oo et al. 2021). Another in situ detections found a significant reducing trend of PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, and CO contents in the ambient air of Bangkok during the COVID-19 outbreak year in comparison with the same periods in 2019 (Wetchayont 2021). In spite of numerous studies focused on the influences of pandemic on reducing air pollutants, there is a rising concern that the psychological and social impact of COVID-19 might have played an important role in various aspects such as societies’ mental health, nursing services of elderly patients, anxiety/depression and suicidal ideation (Meng et al. 2020; Serafini et al. 2020; Sharma et al. 2020; Tee et al. 2020; Yom-Tov et al. 2021). On the contrary, there is a limited number of studies shed light on the intimate relationship between “COVID-19 infected number” and “PM<sub>2.5</sub> level” in the ambient air of urban cities. Overall, the main principles of this study are to (i) elucidate the impacts of COVID-19 daily case reports on the variation of PM<sub>2.5</sub> concentration and (ii) investigate the influences of lockdown policy and hot-spot numbers on the fluctuation of PM<sub>2.5</sub> content in the ambient air of Bangkok in January 2021. It is crucial to underline that all hot-spot numbers were provided by FIRMS (The Fire Information for Resource Management System) which integrates remote sensing and GIS technologies to deliver MODIS (Moderate Resolution Imaging Spectroradiometer) hot-spot positions to GISTDA (The Geo-Informatics and Space Technology Development Agency (Public Organization)). MODIS is a major instrument aboard the Terra (Terra passes from north to south across the equator in the morning) and Aqua (Aqua passes from south to north over the equator in the afternoon) satellites. It is also important to highlight that the MODIS instrument is using both the Terra and Aqua spacecraft. It has a viewing swath width of 2330 km and views the entire surface of the Earth every one to two days. Its detectors measure 36 spectral bands between 0.405 and 14.385 μm, and it acquires data at three spatial resolutions—250 m, 500 m, and 1000 m. In this study, the definition of “hotspot” indicates any fire locations detected by MODIS in the administrative provinces of central Thailand (i.e. Bangkok, Ang Thong, Chai Nat, Kamphaeng Phet, Lopburi, Nakhon Nayok, Nakhon Pathom, Nakhon Sawan, Nonthaburi, Pathum Thani, Phetchabun, Phichit, Phitsanulok, Phra Nakhon Si Ayutthaya, Samut Prakan, Samut

Sakhon, Samut Songkhram, Saraburi, Sing Buri, Sukhothai, Suphan Buri, and Uthai Thani).

## 2 Materials and Method

The Bangkok Metropolitan Administration (BMA) has PM<sub>10</sub> and PM<sub>2.5</sub> air quality monitoring networks over Bangkok area use two US-EPA FEM BAM models BAM-1020 Beta Attenuation Mass Monitor and BAM-1022 Portable Continuous Beta Attenuation Mass Monitor. “BAMs” are generally regarded as the standard for continuous ambient PM<sub>2.5</sub> measurement in air quality monitoring. BAMs is using Beta ray attenuation, which is one of the most widely used methods worldwide for regulatory monitoring of automatically measures and records airborne particulate matter concentration levels in micrograms per cubic meter (μg m<sup>-3</sup>). They are generally simple, reliable, comparatively inexpensive, and relatively easy to operate. BAM-1022 received US-EPA Federal Equivalent Method (FEM) designated PM<sub>2.5</sub> in 2013 and latest modifications in 2019. In addition, all PM<sub>2.5</sub> data were collected by using BAMs located at 49 BMA districts. Some more descriptions on locations and characteristics of the site chosen are described as follows. In this study, there are ten BMA districts (i.e. Bang Bon, Bang Kapi, Bang Khae, Bang Khen, Bang Kho Laem, Bang Khun Thian, Bang Na, Bang Phiat, Bang Rak, and Bang Sue) connected with the Thai word “Bang” which means place and/or location usually near a river or canal. Although there are some unconscious biases related to “Bang” districts as suburban areas and/or outer districts, as they grew into a larger town, these “Bang” districts reaches a population of somewhere between 20,000 and 30,000 people then they will begin to be informally regarded as a city. For instance, Bang Kapi, Bang Rak, and Bang Sue have population of 148,964 persons, 46,472 persons, and 128,995 persons, respectively (Bangkok Metropolitan Administration 2014). It is interesting to note that Nong Chok, Lat Krabang, Bang Khun Thian, and Khlong Sam Wa have comparatively large areas with the values of 236,261 km<sup>2</sup>, 123,859 km<sup>2</sup>, 120,687 km<sup>2</sup>, and 110,686 km<sup>2</sup>, respectively (Bangkok Metropolitan Administration 2014). It is also crucial to underline that Khlong San, Ratchathewi, and Bangkok Yai have relatively high population densities with the values of 12,432 person km<sup>-2</sup>, 10,355 person km<sup>-2</sup>, and 11,327 person km<sup>-2</sup>, respectively (Bangkok Metropolitan Administration, 2014). All statistical analysis was conducted using IBM SPSS Statistics 23. The bivariate Pearson Correlation generates a sample correlation coefficient, *R*, which detects the strength and direction of linear relationships between hot-spot numbers and PM<sub>2.5</sub> contents. Furthermore, the Pearson Correlation assesses whether there is statistical evidence for a linear relationship among the same pairs of hot-spot numbers and PM<sub>2.5</sub>

contents in the population. It is also crucial to note that the data must meet the following requirements which are (i) the values for all parameters (i.e. hot-spot numbers and  $PM_{2.5}$  contents) across cases are unrelated, (ii) the value for any parameter cannot affect the value of any parameter for other cases, (iii) the cases must have non-missing values on both parameters.

In this study, the independent samples *t* test was used to compare the averages of 2 independent groups, which are  $PM_{2.5}$  concentrations detected at 49 districts of BMA as categorized by COVID-19-infected number (*n*) (i.e.  $n < 300$  vs.  $n \geq 300$ ,  $n < 500$  vs.  $n \geq 500$ ,  $n < 700$  vs.  $n \geq 700$ ) to determine whether there is statistical evidence that the related population averages are significantly different. The one-way analysis of variance (ANOVA) is generally employed to evaluate whether there are any statistically significant differences between the averages of  $PM_{2.5}$  contents measured in three different periods (i.e. 01/01/21–10/01/21, 11/01/21–20/01/21, and 21/01/21–31/01/21). It is also important to highlight that the one-way ANOVA is an omnibus test statistic and cannot explain which specific groups were statistically significantly different from each other; it only describes that at least two groups were different. To obtain a valid result, there are several assumptions that need to be passed prior to the statistical analysis. For instance, the dependent parameter (i.e.  $PM_{2.5}$  content) should theoretically be detected at the interval or ratio level. The independent parameter should have independence of observations as well as consist of two or more categorical, independent groups. In addition, there should be no significant outliers and the  $PM_{2.5}$  content should be approximately normally distributed for each monitoring site.

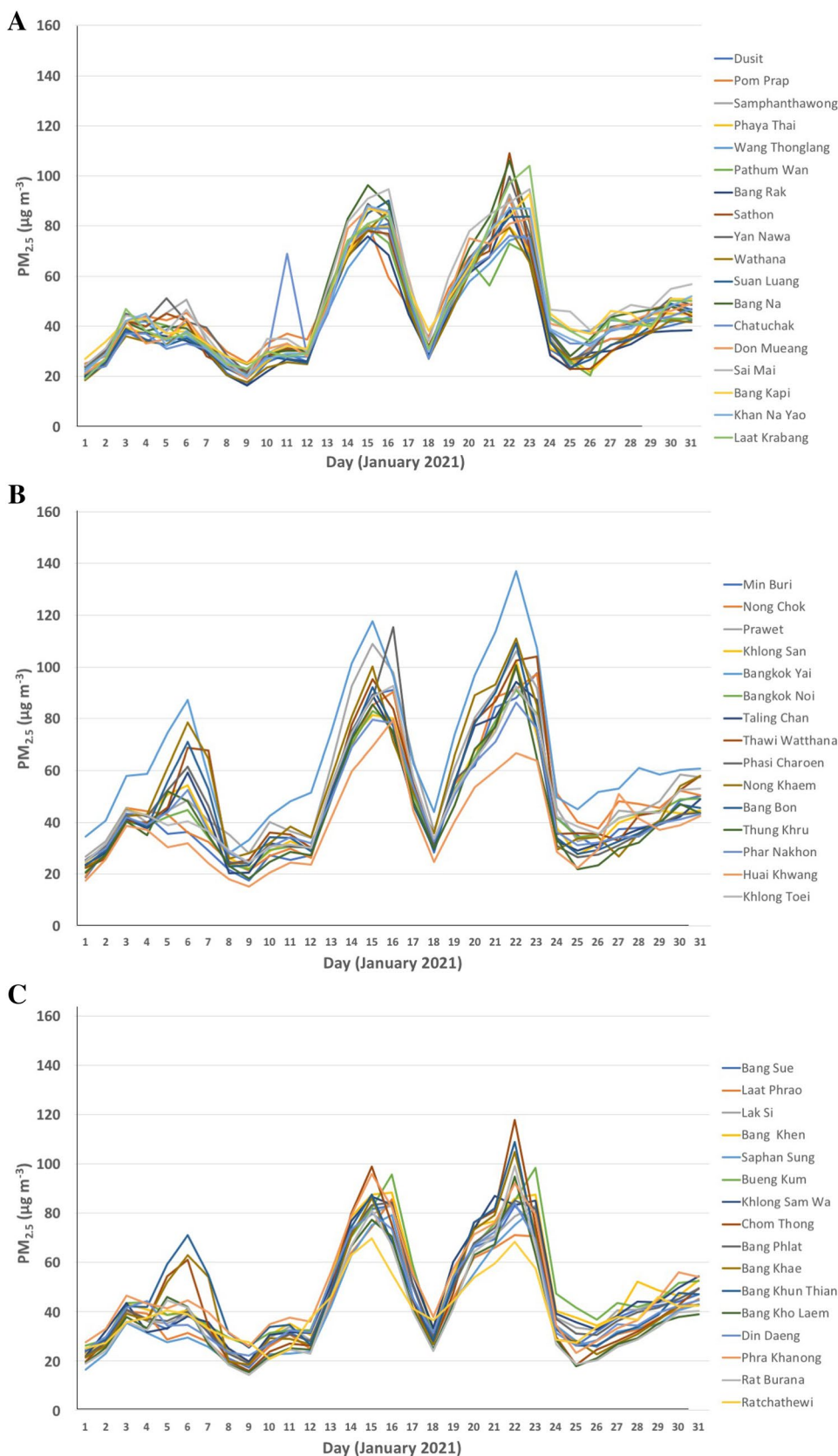
### 3 Results and Discussion

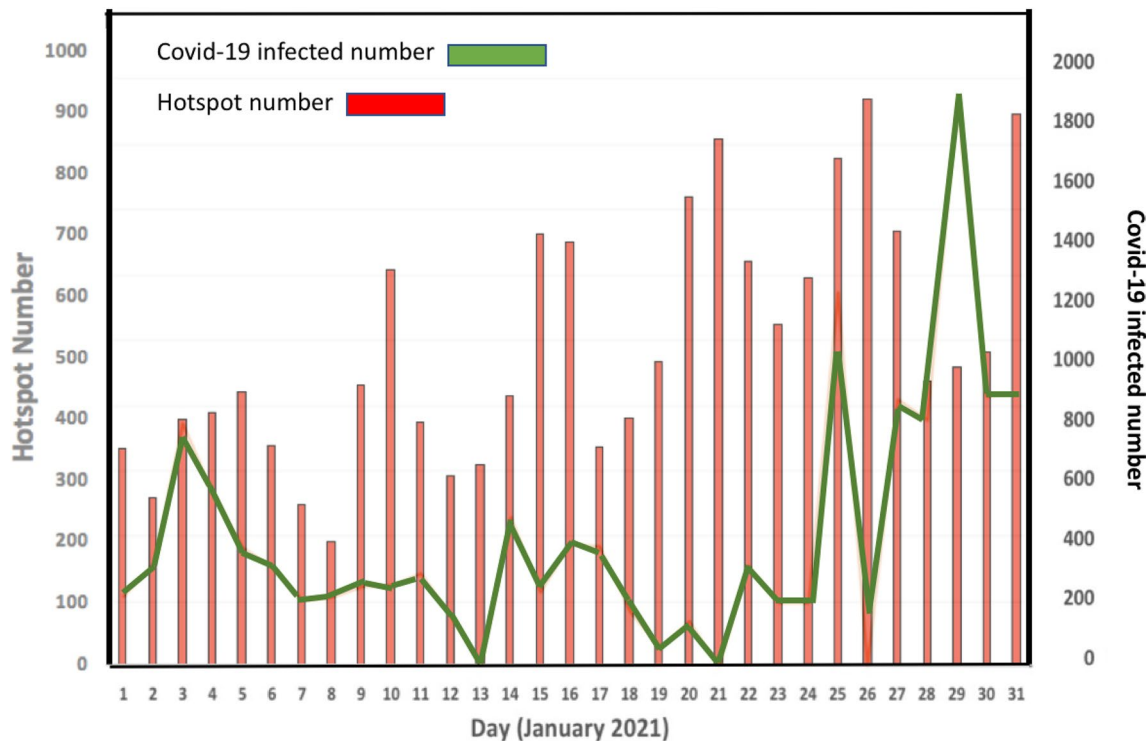
As illustrated in Fig. 1A–C, three main peaks of  $PM_{2.5}$  contents were detected in the first week (i.e. 04/01/21–06/01/21), the second week (i.e. 14/01/21–16/01/21), and the third week (i.e. 21/01/21–23/01/21) of January 2021. The associations of daily peak concentration of  $PM_{2.5}$  with daily COVID-19-infected number and hot-spot number (see Fig. 2) were carefully investigated using *t* test, Analysis of Variance (ANOVA), and Pearson Correlation Analysis (PCA). A *t* test was employed to correlate the arithmetic mean of  $PM_{2.5}$  and COVID-19-infected numbers (*n*) in three different categories which were Group-I (i.e.  $n < 300$  vs.  $n \geq 300$ ), Group-II (i.e.  $n < 500$  vs.  $n \geq 500$ ), and Group-III (i.e.  $n < 700$  vs.  $n \geq 700$ ) (see Table 1). No significant differences ( $p > 0.05$ ) were observed in Group-I indicating that the COVID-19-infected number of 300 can be considered of minor importance for making decisions to work from home (WFH). On the contrary, some significant differences

( $p < 0.05$ ) were detected in air quality observatory sites located in Taling Chan, Phasi Charoen, Nong Khaem, Phar Nakhon, Bang Bon, Bang Khae, and Bang Khun Thian when using the COVID-19-infected numbers of 500 and 700 as illustrated in Table 1. Although these seven districts have comparatively high population with the average value of  $130,842 \pm 46,383$  (i.e. Taling Chan (105,857), Phasi Charoen (129,238), Nong Khaem (153,175), Phar Nakhon (55,373), Bang Bon (107,140), Bang Khae (191,966), Bang Khun Thian (173,144)), the density population is highly deviated with the value in the range of  $1435 \text{ Person km}^{-2}$  (Bang Khun Thian) to  $10,002 \text{ Person km}^{-2}$  (Phar Nakhon) (Bangkok Metropolitan Administration 2014). It appears rationale to conclude that both the population and the density population cannot be used to explain some significant differences between arithmetic mean of  $PM_{2.5}$  and COVID-19-infected numbers observed in these seven districts. As clearly illustrated in Fig. 3, Taling Chan, Phasi Charoen, Nong Khaem, Phar Nakhon, Bang Bon, Bang Khae, and Bang Khun Thian are located in west and southwest of Bangkok. These seven districts are relatively close to Samut Sakhon province, the epidemic hot-spot of the second outbreak of COVID-19 in Thailand. On December 18th 2020, a 67-year-old merchant at a seafood market in Samut Sakhon was tested positive and a few days later up to 1300 persons were also detected with COVID-19. The second wave of outbreak were observed in up to 33 provinces with 28 provinces throughout the nation were declared “red zone” and subjected to lockdown measures (Tan and Lim 2021). The impact of second wave was more pronounced with the volume of cumulative nationwide cases amounted to 24,751-almost tripled the total cases reported in 2020 (Suphanchaimat et al. 2021). As a part of COVID-19 prevention measures, the Royal Thai Government has approved the extension of the Emergency Decree nationwide until 28th February, 2021 to contain the local transmission. The Emergency Decree dramatically decrease the number of passengers travelling to the infected areas adjacent to Bangkok due to some active preventive measures such as closure of areas at risk of infection, a ban on gatherings or illegal assembly in crowded areas, and strict screening of the movement of migrant workers. These active preventive measures can significantly reduce  $PM_{2.5}$  contents particularly during the first week of January, 2021. The fact that all  $PM_{2.5}$  concentrations detected in the above-mentioned BMA districts were significantly lower when the COVID-19-infected numbers were greater than 500 and 700 indicates that the COVID-19-infected situation reports play a major role in governing public decision to WFH.

Further assessment connected with the impacts of WFH on air quality improvement were conducted by categorizing monitoring periods of  $PM_{2.5}$  into three groups namely Group-I (i.e. 01/01/21–10/01/21), Group-II (i.e. 11/01/21–20/01/21), and Group-III (i.e. 21/01/21–31/01/21).

**Fig. 1** **A** Daily variations of  $PM_{2.5}$  contents collected at Dusit, Pom Prap, Samphanthawong, Phaya Thai, Wang Thonglang, Pathum Wan, Bang Rak, Sathon, Yan Nawa, Wathana, Suan Luang, Bang Na, Chatuchak, Don Mueang, Sai Mai, Bang Kapi, Khan Na Yao, and Laot Krabang from 1 to 31st January, 2021. **B** Daily variations of  $PM_{2.5}$  contents collected at Min Buri, Nong Chok, Prawet, Khlong San, Bangkok Yai, Bangkok Noi, Taling Chan, Thawi Watthana, Phasi Charoen, Nong Khaem, Bang Bon, Thung Khru, Phar Nakhon, Huai Khwang, and Khlong Toei from 1 to 31st January, 2021. **C** Daily variations of  $PM_{2.5}$  contents collected at Bang Sue, Laot Phrao, Lak Si, Bang Khen, Saphan Sung, Bueng Kum, Khlong Sam Wa, Chom Thong, Bang Phlat, Bang Khae, Bang Khun Thian, Bang Kho Laem, Din Daeng, Phra Khanong, Rat Burana, and Ratchathewi from 1 to 31st January, 2021





**Fig. 2** Covid-19-infected number and hot-spot number in Thailand from 1 to 31st January 2021

As clearly displayed in Table 2, the levels of  $PM_{2.5}$  were significantly lower in Group-I than other two groups as detected in Chatuchak, Khlong Sam Wa, Ratchathewi, Don Mueang, Sai Mai, Laot Phrao, Lak Si, Bang Khen, Nong Chok, Wang Thonglang, Bang Sue, Din Daeng, Bang Kapi, Saphan Sung, Pathum Wan, Huai Khwang, Phaya Thai, Khlong Toei, Bueng Kum, Bangkok Noi, Khan Na Yao, Wathana, Bang Na, Prawet, Laot Krabang, Dusit, Min Buri, Suan Luang, Phra Khanong, Bang Rak, Bang Phlat, Pom Prap, and Phar Nakhon. These significant differences detected at the 33 districts can be ascribed to several reasons, including geographical locations and pollution sources. Previous studies highlight traffic emissions as one of the major sources of  $PM_{2.5}$  in ambient air of Bangkok (ChooChuay et al. 2020a; Pongpiachan and Iijima 2016; Pongpiachan et al. 2015, 2017). It is well known that these 33 districts have comparatively higher traffic volume in comparison with those of other 16 districts (i.e. Yan Nawa, Samphanthawong, Sathon, Thung Khru, Taling Chan, Khlong San, Bangkok Yai, Phasi Charoen, Rat Burana, Bang Kho Laem, Chom Thong, Thawi Watthana, Bang Bon, Nong Khaem, Bang Khae, and Bang Khun Thian). For instance, the number of vehicles at intersections of Kaset (Bang Khen), Democracy Monument (Ratchathewi), Prasert Manukitch Lat Pla Kha (Laot Phrao), Klong Prapa (Bang Sue), and Thiam Ruam Mit (Huai Khwang) have number of vehicles per day with the values of 156,442, 132,011, 109,572, 108,063, and

105,804, respectively (Bangkok Metropolitan Administration 2019). The average traffic volume of these five districts (i.e.  $122,378 \pm 21,776$ ) was almost 4.9, 6.0, and 7.3 times higher than those of Sathon (i.e. Witthayu; 25,096), Thung Kru (i.e. Phacha U Tit & Kru Nai; 20,528), and Yan Nawa (i.e. Naret; 16,848), respectively (Bangkok Metropolitan Administration 2019).

It is also interesting to note that some significant reductions of  $PM_{2.5}$  were observed in the eastern parts of Bangkok as illustrated in Fig. 3. This can be explained by the fact that the majority of business districts and commercial zone are more likely to be concentrated in the eastern part of Bangkok than the western region. Thus, it appears rationale to assume that the implemented quarantine measures tend to play a major role in reducing  $PM_{2.5}$  levels particularly in the business areas of eastern Bangkok. In this study, the hot-spot numbers in Thailand from 1 to 31st January 2021 were also carefully analyzed using Pearson Correlation Analysis (PCA) to correlate with  $PM_{2.5}$  contents collected at 49 districts of BMA in January 2021. As shown in Fig. 4, the correlation coefficients of hot spots were comparatively low with the values of  $R < 0.4$ . On the contrary, the relatively high correlation coefficients of  $R > 0.9$  were observed with  $PM_{2.5}$  collected within different BMA air quality observatory sites. These findings underline the importance of traffic emissions as one of the main contributors of  $PM_{2.5}$  in BMA districts during the observatory period.

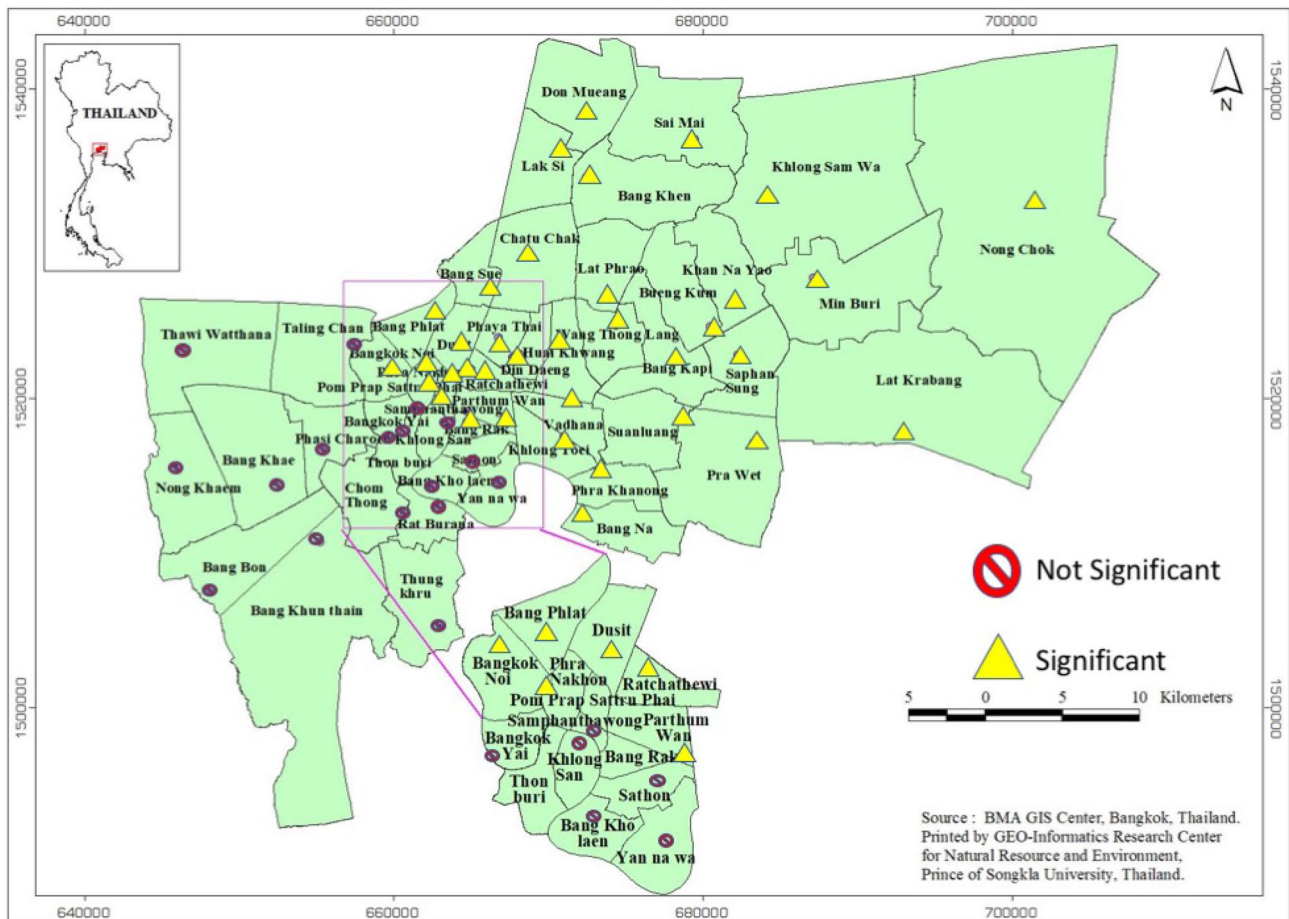
**Table 1** Statistical descriptions of PM<sub>2.5</sub> concentrations detected at 49 districts of BMA as categorized by COVID-19-infected number

COVID-19-infected number	<300	≥300	<i>p</i> <0.05	<500	≥500	<i>p</i> <0.05	<700	≥700	<i>p</i> <0.05
PM <sub>2.5</sub> (μg m <sup>-3</sup> )	Aver	Aver		Aver	Aver		Aver	Aver	
Dusit	40±21	45±19	NS	45±22	36±5.1	NS	44±22	36±5.4	NS
Pom Prap	45±19	47±17	NS	48±20	40±8.9	NS	48±19	40±9.5	NS
Samphanthawong	43±20	48±18	NS	48±21	39±6.2	NS	47±21	39±6.7	NS
Phaya Thai	40±20	45±17	NS	45±21	38±7.1	NS	44±21	38±7.6	NS
Wang Thonglang	41±18	47±16	NS	45±20	42±1.6	NS	45±19	42±1.8	NS
Pathum Wan	40±19	46±15	NS	44±20	40±6.1	NS	44±19	40±6.6	NS
Bang Rak	38±20	43±18	NS	42±21	34±5.5	NS	42±21	34±5.8	NS
Sathon	41±20	48±22	NS	47±23	38±8.0	NS	47±23	37±8.6	NS
Yan Nawa	45±22	51±19	NS	50±23	42±7.3	NS	49±23	42±7.9	NS
Wathana	39±21	44±19	NS	43±22	36±5.1	NS	43±22	36±5.4	NS
Suan Luang	42±23	46±20	NS	46±34	38±8.1	NS	46±24	38±8.6	NS
Bang Na	46±24	51±23	NS	51±27	42±6.5	NS	51±26	43±6.8	NS
Chatuchak	44±20	46±17	NS	46±21	40±4.5	NS	46±21	40±4.7	NS
Don Mueang	45±23	50±18	NS	49±23	42±5.0	NS	48±23	43±3.7	NS
Sai Mai	49±25	55±19	NS	53±25	48±5.1	NS	53±25	49±5.1	NS
Bang Kapi	47±22	51±16	NS	50±22	45±4.7	NS	50±22	45±5.1	NS
Khan Na Yao	44±23	50±18	NS	48±24	43±5.5	NS	48±24	43±5.9	NS
Laat Krabang	45±25	50±20	NS	49±26	43±5.0	NS	49±25	44±4.9	NS
Min Buri	44±26	49±19	NS	48±26	42±5.4	NS	48±26	42±5.8	NS
Nong Chok	46±25	53±18	NS	50±25	47±3.8	NS	50±25	47±3.9	NS
Prawet	53±26	57±23	NS	58±27	46±8.6	NS	58±27	47±8.8	NS
Khlong San	44±20	52±20	NS	50±22	41±5.8	NS	50±22	41±6.2	NS
Bangkok Yai	64±30	70±25	NS	71±31	57±5.4	NS	70±31	57±5.8	S
Bangkok Noi	43±21	48±18	NS	48±22	41±5.0	NS	47±22	41±5.4	NS
Taling Chan	46±24	49±19	NS	50±24	39±5.8	S	50±24	39±6.3	NS
Thawi Watthana	51±27	54±21	NS	55±27	43±8.3	NS	55±27	44±8.8	NS
Phasi Charoen	45±21	53±27	NS	52±27	38±6.7	S	52±26	38±7.0	S
Nong Khaem	52±27	54±23	NS	57±27	42±10	S	57±27	42±11	S
Bang Bon	47±24	51±22	NS	53±26	39±6.5	S	52±25	39±7.0	S
Thung Khru	41±22	48±21	NS	47±24	36±8.2	NS	46±23	36±8.8	NS
Phar Nakhon	44±19	48±17	NS	48±20	38±4.3	S	48±20	38±4.7	S
Huai Khwang	35±18	43±16	NS	39±19	39±8.0	NS	39±19	39±8.6	NS
Khlong Toei	46±21	53±19	NS	50±23	45±5.2	NS	50±23	45±5.5	NS
Bang Sue	42±21	47±18	NS	46±22	40±6.3	NS	45±22	40±6.7	NS
Laat Phrao	40±20	43±17	NS	44±21	37±6.0	NS	43±21	36±6.4	NS
Lak Si	43±21	48±17	NS	47±22	41±5.0	NS	47±21	42±5.0	NS
Bang Khen	46±23	52±18	NS	50±24	45±6.0	NS	50±23	46±6.2	NS
Saphan Sung	37±22	42±17	NS	41±22	35±4.9	NS	41±22	35±5.1	NS
Bueng Kum	47±22	52±18	NS	51±23	45±4.2	NS	51±23	46±4.5	NS
Khlong Sam Wa	47±24	50±18	NS	50±24	43±7.4	NS	49±24	44±6.3	NS
Chom Thong	42±26	50±25	NS	49±29	36±9.5	NS	49±28	36±10	NS
Bang Phlat	45±23	51±19	NS	50±24	42±5.5	NS	50±23	42±5.9	NS
Bang Khae	43±23	47±21	NS	48±25	35±6.1	S	48±24	35±6.6	S
Bang Khun Thian	46±22	51±22	NS	52±24	39±7.6	S	51±24	38±8.1	S
Bang Kho Laem	37±20	43±20	NS	42±23	32±7.1	NS	42±22	32±7.7	NS
Din Daeng	42±20	46±17	NS	46±21	39±6.3	NS	46±21	38±6.3	NS
Phra Khanong	48±22	51±20	NS	52±23	42±11	NS	52±22	42±12	NS
Rat Burana	37±22	43±21	NS	42±24	32±7.3	NS	42±23	32±7.9	NS

**Table 1** (continued)

COVID-19-infected number	<300	≥ 300	<i>p</i> < 0.05	<500	≥ 500	<i>p</i> < 0.05	<700	≥ 700	<i>p</i> < 0.05
PM <sub>2.5</sub> (µg m <sup>-3</sup> )	Aver	Aver		Aver	Aver		Aver	Aver	
Ratchathewi	42 ± 14	43 ± 12	NS	44 ± 14	38 ± 5.6	NS	43 ± 14	38 ± 6.1	NS

“S” and “NS” stand for “Significance” and “Non-Significance”, respectively



**Fig. 3** A map of Bangkok as classified by the significant levels of ANOVA test by using PM<sub>2.5</sub> concentrations collected at 49 districts at 3 different monitoring periods

### 4 Conclusions

Numerous empirical investigations underline the importance of lockdown policy as one of key factors which dramatically reduce air pollutants in ambient air around the world particularly in the middle of pandemic. Earlier, there was no clarity whether the COVID-19-infected number can psychologically affect decision making on self-quarantine during the coronavirus crisis. PM<sub>2.5</sub> contents observed in some BMA districts were significantly lower when the COVID-19-infected numbers were larger

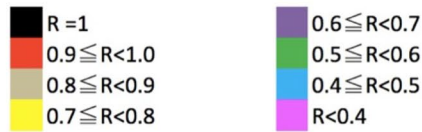
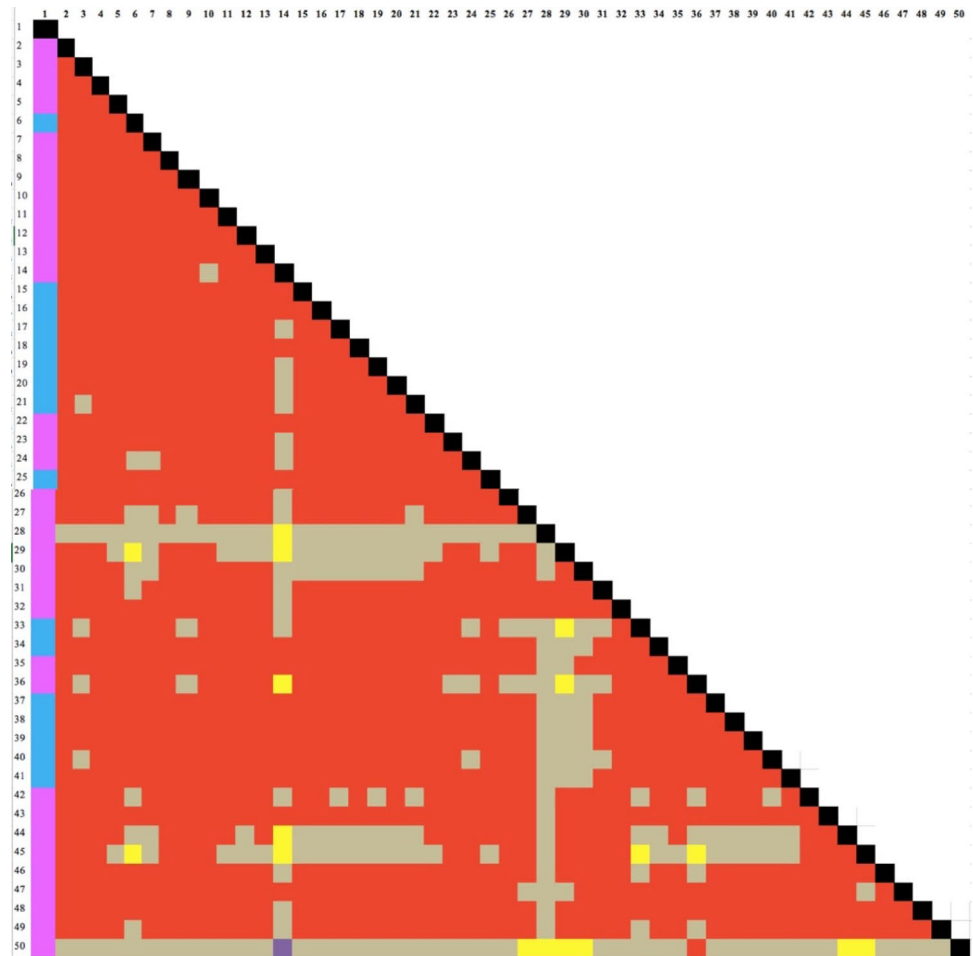
than 500 and 700 underlines the importance of WFH for improving air quality. The second outbreak can significantly reduce PM<sub>2.5</sub> levels detected in eastern part of Bangkok particularly during the first week of January, 2021. In addition, the relatively low Pearson’s correlation coefficients between hot-spot numbers and PM<sub>2.5</sub> concentrations indicates that agricultural waste burnings can be considered as the second contributor after vehicle exhausts.

**Table 2** ANOVA test of PM<sub>2.5</sub> concentrations detected at 49 districts of BMA as categorized by 3 different monitoring periods

Sampling period	01/01/21–10/01/21		11/01/21–20/01/21		21/01/21–31/01/21		Significance tests
	Aver	Stdev	Aver	Stdev	Aver	Stdev	
Chatuchak	29	5.9	56	19	47	16	S
Khlong Sam Wa	31	7.3	58	21	51	19	S
Ratchathewi	33	5.7	50	12	42	13	S
Don Mueang	31	8.1	58	23	50	17	S
Sai Mai	34	9.1	62	24	57	19	S
Laat Phrao	28	7.8	53	20	42	16	S
Lak Si	31	7.0	55	20	49	18	S
Bang Khen	33	8.3	59	22	52	19	S
Nong Chok	32	9.5	56	22	56	21	S
Wang Thonglang	31	7.2	51	20	48	15	S
Bang Sue	30	8.2	54	21	46	18	S
Din Daeng	31	7.5	54	19	44	19	S
Bang Kapi	34	6.3	56	20	53	19	S
Saphan Sung	25	6.4	48	21	43	20	S
Pathum Wan	32	8.4	54	19	43	17	S
Huai Khwang	26	8.3	46	19	42	15	S
Phaya Thai	30	7.5	53	20	43	19	S
Khlong Toei	34	7.2	58	23	52	19	S
Bueng Kum	34	6.9	57	22	54	21	S
Bangkok Noi	32	7.9	55	20	48	20	S
Khan Na Yao	31	8.4	55	22	50	20	S
Wathana	28	7.5	51	22	42	17	S
Bang Na	32	7.2	59	25	52	24	S
Prawet	38	7.4	67	27	56	24	S
Laat Krabang	31	8.3	54	21	54	25	S
Dusit	29	8.6	52	21	44	19	S
Min Buri	30	9.2	55	24	51	23	S
Suan Luang	29	6.9	54	24	45	22	S
Phra Khanong	37	7.2	61	21	48	23	S
Bang Rak	28	8.1	49	19	41	20	S
Bang Phlat	34	9.7	57	22	50	22	S
Pom Prap	35	7.9	54	16	46	21	S
Phar Nakhon	35	9.2	54	18	45	19	S
Yan Nawa	35	9.9	56	21	49	22	NS
Samphanthawong	34	9.6	53	19	46	21	NS
Sathon	33	8.8	54	19	46	26	NS
Thung Khru	32	12	53	21	44	24	NS
Taling Chan	35	13	56	22	48	24	NS
Khlong San	36	12	55	20	49	22	NS
Bangkok Yai	51	19	77	25	68	30	NS
Phasi Charoen	38	13	61	29	45	24	NS
Rat Burana	28	10	48	21	40	25	NS
Bang Kho Laem	29	11	48	20	39	23	NS
Chom Thong	33	15	55	26	46	30	NS
Thawi Watthana	40	17	59	23	54	27	NS
Bang Bon	39	16	57	23	48	26	NS
Nong Khaem	43	19	62	23	51	28	NS
Bang Khae	36	16	52	21	44	26	NS
Bang Khun Thian	41	16	54	22	46	26	NS



**Fig. 4** Pearson correlation coefficients between hot-spot numbers and PM<sub>2.5</sub> contents collected at 49 districts of BMA in January 2021



1 Hot Spots	11 Wathana	21 Nong Chok	31 Thung Khru	41 Khlong Sam Wa
2 Dusit	12 Suan Luang	22 Prawet	32 Phar Nakhon	42 Chom Thong
3 Pom Prap	13 Bang Na	23 Khlong San	33 Huai Khwang	43 Bang Phlat
4 Samphanthawong	14 Chatuchak	24 Bangkok Yai	34 Khlong Toei	44 Bang Khae
5 Phaya Thai	15 Don Mueang	25 Bangkok Noi	35 Bang Sue	45 Bang Khun Thian
6 Wang Thonglang	16 Sai Mai	26 Taling Chan	36 Laot Phrao	46 Bang Kho Laem
7 Pathum Wan	17 Bang Kapi	27 Thawi Watthana	37 Lak Si	47 Din Daeng
8 Bang Rak	18 Khan Na Yao	28 Phasi Charoen	38 Bang Khen	48 Phra Khanong
9 Sathon	19 Laot Krabang	29 Nong Khaem	39 Saphan Sung	49 Rat Burana
10 Yan Nawa	20 Min Buri	30 Bang Bon	40 Bueng Kum	50 Ratchathewi

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## Declarations

**Competing interests** None declared.

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