SEHS science, engineering and health studies

Research Article

Science, Engineering and Health Studies
https://li01.tci-thaijo.org/index.php/sehs
ISSN (Online): 2630-0087

Impact of meteorological factors on the COVID-19 pandemic in Thailand

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***Received**: 24 May 2022*
***Revised**: 5 December 2022*
***Accepted**: 6 December 2022*
***Published**: 30 December 2022*

***Citation**: Saengchut, P., Ruksakulpiwat, S., Wonglertarak, W., Kokaphan, C., and Phengarree, K. (2022). Impact of meteorological factors on the COVID-19 pandemic in Thailand. Science, Engineering and Health Studies, 16, 22050024.*

ABSTRACT

Meteorological factors such as humidity, wind speed, rainfall, and temperature have been found to impact the spread of COVID-19. However, there is still a lack of studies on this aspect in Thailand. Therefore, this study aimed to determine the impact of meteorological factors on the COVID-19 pandemic in Thailand. The data regarding the number of COVID-19 patients between January to May 2021 and meteorological factors from 12 provinces in Thailand were retrieved from Thai Digital Government Development Agency and Thai Meteorological Department, respectively. The differences in meteorological factors in 12 provinces, and between meteorological factors were analyzed. Multiple regression method was used to examine the impact of meteorological factors on the number of COVID-19 patients. The number of COVID-19 patients in Thailand in the third pandemic wave was higher than in the first and second waves. The cumulative patients of the third wave since January-May 2021 in Bangkok, Chiang Mai, Samut Prakan, and Chon Buri were among the highest. The meteorological factors in each province, including relative humidity, wind speed, and temperature, were significantly different. Furthermore, a significant association between temperature and the number of COVID-19 patients was found. Finally, the multiple regression analysis showed that the temperature factor could significantly predict the number of COVID-19 patients. The result from this study may be useful for future study aimed at determining a strategy to prevent the COVID-19 pandemic cause by meteorological factors.

Keywords: climate factors; covid-19; statistical association; Thailand

1. INTRODUCTION

Since 2019, the outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), or COVID-19, has spread to many countries. The report from WHO shows that on July 21, 2021, the confirmed COVID-19 cases were 74,411,952 in the USA, 57,636,847 cases in Europe, 36,525,388 cases in South-East Asia, 11,644,006 cases in

Eastern Mediterranean, 4,531,636 cases in Africa, and 3,905,375 cases in Western Pacific (Ciotti et al., 2020). At the time of writing (November 24, 2022), the total number of confirmed COVID-19 cases in Thailand was 4,702,330, with 33,106 death and 4,649,509 recovered (Worldometer, 2022). COVID-19 is transmitted between people in various ways, such as coughing, sneezing, speaking, or breathing (WHO, 2020a). The virus is spread mainly among people close to each other within 1 meter. Moreover, it also spreads in poorly ventilated places (WHO, 2020a).

The influence of different meteorological factors on COVID-19 spreading, for example, temperature, relative humidity, and wind speed, could be the reason for the different COVID-19 pandemic rates in different areas (WHO, 2020b). The previous study explained the association between the spreading of viral infection and meteorological factors. The result found that low temperatures are associated with the spreading of the virus (Mecenas et al., 2020; Chan et al., 2011; Mourtzoukou and Falagas, 2007). Moreover, the previous literature found that high relative humidity reduces the spread of the virus, which is a potential factor in disease prevention and control (Jia et al., 2020). However, factors such as rainfall slightly impacted the spreading of COVID-19 (Wang et al., 2020).

Thailand is located in a tropical area. Therefore, weather and meteorological conditions in this country can be divided into five parts: northern, northeastern, central, eastern, and southern. Meteorological conditions are different as each part is located in a different area (Thai Meteorological Department, 2021). The weather in Thailand is influenced by monsoon winds, which bring warm moist air in May and cold and dry air in October. Therefore, the differences in meteorological conditions in different areas may play a role in the spread of COVID-19 in each part and still need to be confirmed with more empirical evidence. As far as we know, no studies have been conducted to examine the impact of meteorological factors on the COVID-19 pandemic in Thailand.

Therefore, this study aimed to determine the association between the number of COVID-19 patients and meteorological factors in 12 provinces.

2. MATERIALS AND METHODS

2.1 Scope of data

In this study, the data regarding the number of COVID-19 patients in 2021 (Digital Government Development Agency, 2020) and meteorological factors data, including relative humidity (%), wind speed (m/s), rainfall (mm), and temperature (°C) were extracted from Thai Digital Government Development Agency Data and Thai Meteorological Department, respectively. The provinces, where the number of COVID-19 patients has more than 1,000 during January-May 2021, including Bangkok, Chachoengsao, Chon Buri, Chiang Mai, Nakhon Pathom, Pathum Thani, Prachuap Khiri Khan, Ayutthaya, Rayong, Songkhla, Samut Prakan and Surat Thani, were selected to include in the data analysis (Figure 1).

2.2 Scope of data analysis

The difference in meteorological factors in 12 provinces was analyzed using the one-way ANOVA test at a 0.05 significance level. Secondly, the double-difference datasets between meteorological factors were analyzed using the Scheffe method at a 0.05 significance level. Moreover, Pearson correlation statistics were used to determine the correlation between meteorological factors and the number of COVID-19 patients. Finally, the stepwise multiple regression method was used to examine the impact of meteorological factors on the number of COVID-19 patients. The regression assumptions (the variety of variables, influence case, and linearity) have been tested before regression analysis is conducted, and the violation has not been found. The data analysis was conducted using SPSS software version 17.0.

3. RESULTS AND DISCUSSION

3.1 COVID-19 pandemic in Thailand

The number of COVID-19 patients was high in Thailand during the third wave of the COVID-19 pandemic, compared to the previous wave. The COVID-19 pandemic report in 2021 from the Department of Disease Control of Thailand (Digital Government Development Agency, 2020) showed four provinces with the highest number of patients in January, including Chon Buri (87 patients), Bangkok (51 patients), Samut Prakan (45 patients), and Rayong (44 patients). In February, Pathum Thani (82 patients), Bangkok (36 patients), and Samut Prakan (10 patients) were the three provinces with the highest number of COVID-19 patients. In March, three provinces demonstrated the highest number of patients, including Bangkok (364 patients), Pathum Thani (20 patients), and Samut Prakan (18 patients). In April, provinces with a high number of patients included Bangkok (1,320 patients), Chiang Mai (319 patients), and Chon Buri (199 patients). In May, the four provinces with the highest number of patients included Bangkok (4,707 patients), Chiang Mai (3,937 patients), Chachoengsao (820 patients), and Samut Prakan (457 patients). The overall cumulative patients in Thailand, since January-May 2021, showed that Bangkok (62,259 patients), Chiang Mai (8,561 patients), Samut Prakan (8,007 patients), and Chon Buri (5,766 patients) were among the area with the highest number of COVID-19 reported.

3.2 Meteorological factors

Twelve provinces with different meteorological factors (relative humidity, wind speed, rainfall, and temperature) during January-May 2021 are shown in Table 1. The highest relative humidity was in April, with the maximum in Chachoengsao (97.23%). When considering the top 5 average relative humidity, it is found that Surat Thani (95.42%) was higher than Nakhon Pathom (94.60%), Chachoengsao (94.26%), Pathum Thani (91.75%), and Ayutthaya (86.90%), respectively. The highest wind speed was in January, with the maximum found in Ayutthaya (9.29 m/s). When considering to top 5 average wind speeds by provinces, it is found that Ayutthaya (4.99 m/s) was higher than Samut Prakan (4.39 m/s), Rayong (4.14 m/s), Chachoengsao (3.67 m/s), and Chon Buri (3.57 m/s), respectively. The rainfall was the highest in February, with the maximum amount in Bangkok (40.35 mm). The top 5 average rainfall by provinces were Bangkok (15.12 mm), Ayutthaya (14.08 mm), Pathum Thani (13.09 mm), Prachuap Khiri Khan (11.73 mm), and Chachoengsao (11.67 mm). In addition, the highest temperature was in May, with a maximum temperature in Bangkok at 31.61°C. The top 5 average temperatures by provinces showed that Bangkok (30.03°C) was higher than Pathum Thani (29.77°C), Chon Buri (29.32°C), Ayutthaya (29.20°C), and Samut Prakan (29°C), respectively.

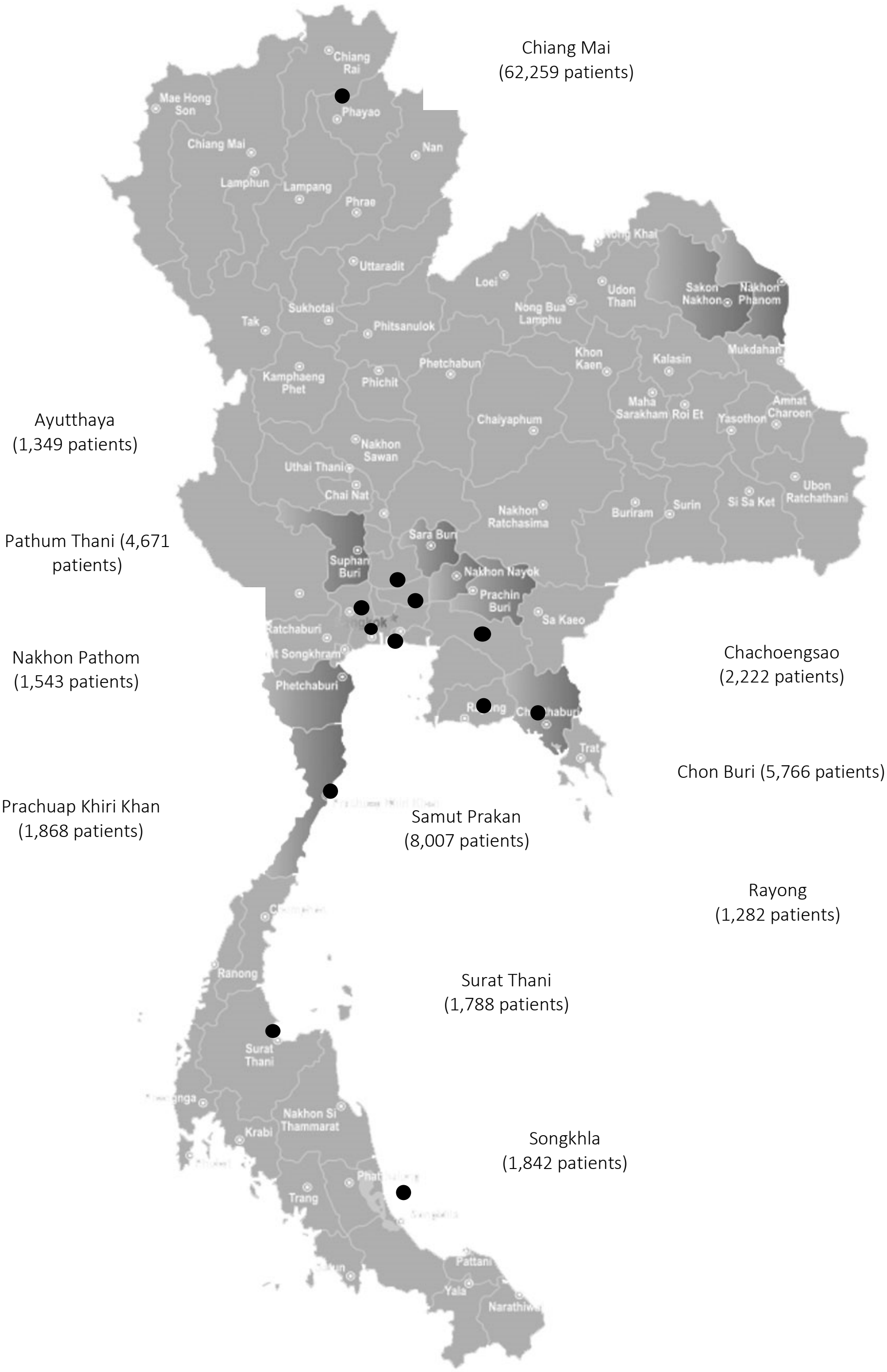

Figure 1. Number of COVID-19 patients by provinces in Thailand (Nicepng, 2021)

Table 1. Meteorological factors of relative humidity, wind, rainfall, and temperature by months in different provinces in Thailand during January and May 2021

Province / number of COVID-19 patient	**Monthly relative humidity average (%) (min-max)**					**Monthly wind speed average (m/s) (min-max)**				
	January	**February**	**March**	**April**	**May**	**January**	**February**	**March**	**April**	**May**
Bangkok (62,259 patients)	75.27 (54-93)	82.32 (82-98)	85.84 (78-93)	88.12 (81-94)	86.58 (72-98)	2.86 (1-6)	2.14 (1-3)	2.50 (2-6)	1.63 (1-2)	1.20 (1-2)
Chachoengsao (2,222 patients)	89.27 (67-97)	93.64 (82-98)	95.12 (85-99)	97.23 (96-99)	96.21 (92-99)	5.00 (4-6)	1.02 (0-3)	N/A	N/A	N/A
Chon Buri (5,766 patients)	76.81 (61-93)	86.24 (72-94)	85.92 (62-96)	89.31 (77-98)	84.92 (68-94)	5.94 (2-18)	3.22 (1-7)	2.81 (2-7)	2.15 (2-3)	2.73 (2-5)
Chiang Mai (8,561 patients)	86.46 (64-94)	80.96 (66-91)	72.12 (60-82)	82.88 (63-92)	79.33 (72-91)	3.50 (2-5)	4.50 (2-7)	N/A	3.00 (1-4)	2.67 (2-4)
Nakhon Pathom (1,543 patients)	93.77 (60-100)	96.68 (77-100)	95.48 (70-100)	93.46 (81-100)	93.63 (80-100)	2.20 (1-4)	2.00 (1-3)	1.67 (1-3)	2.00 (1-3)	1.50 (1-2)
Pathum Thani (4,671 patients)	87.46 (60-97)	93.88 (77-98)	93.84 (76-98)	93.88 (82-98)	89.67 (74-97)	2.67 (2-4)	2.38 (1-4)	1.78 (1-3)	2.83 (1-5)	3.00 (1-5)
Prachuap Khiri Khan (1,868 patients)	80.12 (58-96)	88.76 (76-96)	87.40 (78-95)	86.62 (73-97)	85.29 (73-93)	3.53 (2-8)	3.50 (2-6)	3.00 (2-4)	3.00 (2-4)	3.30 (2-4)
Ayutthaya (1,349 patients)	79.50 (57-94)	87.76 (75-93)	88.16 (68-94)	90.54 (83-94)	88.75 (76-95)	9.29 (3-22)	5.08 (2-12)	3.74 (2-12)	3.44 (2-6)	3.73 (2-9)
Rayong (1,282 patients)	83.08 (57-96)	88.64 (73-97)	85.48 (78-96)	88.54 (79-97)	88.08 (70-96)	3.71 (1-16)	4.40 (2-8)	3.80 (2-6)	3.17 (2-4)	6.00 (3-10)
Songkhla (1,846 patients)	83.27 (77-88)	84.28 (71-92)	84.64 (74-94)	86.23 (81-92)	86.04 (78-95)	2.39 (1-4)	2.30 (1-6)	2.11 (1-6)	2.05 (1-4)	1.81 (1-3)
Samut Prakan (8,007 patients)	81.46 (58-96)	86.20 (72-97)	82.08 (66-94)	86.65 (78-96)	82.88 (70-94)	4.20 (1-16)	3.74 (2-12)	5.30 (3-10)	4.10 (2-8)	N/A
Surat Thani (1,788 patients)	95.19 (89-98)	94.88 (92-96)	94.76 (92-96)	96.69 (95-99)	95.54 (92-97)	2.00 (1-3)	1.00 (0-2)	2.00 (1-3)	1.50 (1-2)	1.89 (1-4)
Province / number of COVID-19 patient	**Monthly rainfall average (mm) (min-max)**					**Monthly temperature average (°C) (min-max)**				
	January	**February**	**March**	**April**	**May**	**January**	**February**	**March**	**April**	**May**
Bangkok (62,259 patients)	N/A	40.35 (0.1-80.6)	1.10 (0.1-4.2)	9.66 (0.5-30.6)	16.40 (0.7-80.2)	27.17 (22.2-30.1)	29.25 26.6-30.9)	31.05 (29.7-32.8)	31.21 (28.6-33.1)	31.61 (28.6-33.6)
Chachoengsao (2,222 patients)	N/A	14.35 (1.1-27.6)	9.00 (0.01-26.1)	16.01 (0.01-58.8)	6.91 (0.7-27.8)	25.18 (19.7-28.8)	27.43 (25.1-30.6)	29.68 (27.1-31.3)	29.49 (27.4-31.7)	30.04 (27.1-31.9)
Chon Buri (5,766 patients)	N/A	1.80 (0.1-3.5)	30.43 (0.6-105.4)	5.12 (0.1-27.7)	12.16 (0.3-36.5)	26.75 (21.9-30)	28.82 (27.6-30.3)	30.28 (28.2-32.1)	30.16 (27.8-32.2)	30.74 (27.9-32.2)
Chiang Mai (8,561 patients)	12.20 (1.3-23.1)	1.56 (0.01-3.1)	4.70 (0.2-9.2)	10.74 (0.01-33.7)	1.98 (0.01-15.6)	23.66 (17-26.9)	25.88 (22.4-28.9)	28.16 (6.9-33.2)	29.38 (21.9-32.5)	31.24 (28.6-33.6)

Table 1. Meteorological factors of relative humidity, wind, rainfall, and temperature by months in different provinces in Thailand during January and May 2021 (Continued)

Province / number of COVID-19 patient	Monthly rainfall average (mm) (min-max)					Monthly temperature averages (°C) (min-max)				
	January	February	March	April	May	January	February	March	April	May
Nakhon Pathom (1,543 patients)	N/A	N/A	18.40 (2.4-65.2)	14.04 (0.01-61.2)	8.53 (0.4-29.5)	23.37 (18.8-27.9)	24.08 (17.8-27.7)	31.45 (14.6-31.8)	30.28 (27-32.2)	30.83 (27.2-32.9)
Pathum Thani (4,671 patients)	N/A	0.10 (0.01-0.3)	12.50 (0.5-24)	6.58 (0.01-26.4)	20.95 (0.01-74.8)	26.40 (21.4-30)	28.77 (27-31.1)	31.26 (29-32.8)	31.10 (27.7-33.6)	31.45 (28.6-33.1)
Prachuap Khiri Khan (1,868 patients)	7.10 (1-13.2)	13.53 (6.7-18.7)	6.10 (3-9.2)	12.06 (0.01-45)	13.87 (0.5-62)	25.52 (21.1-28)	26.52 (24.8-28.7)	29.06 (27.1-31.1)	29.69 (25.6-31.7)	30.44 (27.4-31.8)
Ayutthaya (1,349 patients)	N/A	3.80 (1.1-6.8)	6.60 (2.4-35.6)	5.86 (0.3-27.5)	41.93 (31.5-59.5)	25.41 (19.9-28.9)	27.86 (25.8-30.5)	31.07 (28.1-32.6)	30.94 (28.3-33.1)	30.85 (25.9-32.6)
Rayong (1,282 patients)	N/A	9.68 (0.01-44.7)	16.20 (0.01-34.1)	5.69 (0.1-13.7)	11.52 (0.01-37.5)	25.50 (22.3-27.8)	27.30 (25.4-29)	29.32 (26.5-30.6)	29.58 (27.2-31.4)	29.88 (26.4-32.1)
Songkhla (1,846 patients)	7.08 (0.01-21.9)	2.43 (0.01-9.5)	15.73 (1.7-39.9)	6.97 (0.01-27.4)	8.42 (0.01-36.9)	27.14 (25-28.4)	27.44 (26-28.5)	28.67 (27.5-30)	29.31 (28.3-30.8)	29.27 (27.2-31.4)
Samut Prakan (8,007 patients)	N/A	34.10 (0.1-55.6)	3.00 (0.2-5.8)	8.26 (0.01-31.6)	8.59 (0.01-28.6)	26.07 (20.8-29.7)	28.45 (27-29.7)	30.04 (28.7-31.4)	30.04 (28.1-31.5)	30.54 (27.7-32.3)
Surat Thani (1,788 patients)	2.80 (0.2-12)	0.16 (0.01-0.3)	0.55 (0.4-0.7)	8.51 (0.01-74.2)	6.10 (0.01-15.5)	26.27 (23.1-27.5)	27.32 (25.6-28.5)	28.70 (27.4-30.6)	29.50 (28.5-30.9)	29.25 (26.8-31.2)

The one-way ANOVA test was used to determine the difference in meteorological factors and the number of COVID-19 patients in 12 provinces. The results showed that the number of COVID-19 patients, relative humidity, wind speed, and temperature were significantly different ($p<0.05$). In contrast, the rainfall factor showed statistical indifference ($p = 0.728$), as shown in Supplementary Table S1.

Three meteorological factors, including relative humidity, wind speed, and temperature, have been significantly differed, when analyzing the double-difference datasets between provinces using the Scheffe method (Supplementary Table S2). The results showed that 66 couples were statistically significant, including the relative humidity factor [$F(11, 1083) = 19.633$, $p<0.05$], the wind speed factor [$F(11, 1497) = 26.492$, $p<0.05$] and temperature factor [$F(11, 1500) = 23.410$, $p<0.05$].

3.3 The impact of meteorological factors on the number of COVID-19 patients

The results shown in Table 2 demonstrate that relative humidity correlated with the number of COVID-19 patients in Chon Buri ($R = 0.212$, $p<0.05$). Wind speed correlated with the number of COVID-19 patients in Pathum Thani ($R = 0.203$, $p<0.05$). Rainfall correlated with the number of COVID-19 patients in Songkhla ($R = 0.321$, $p<0.05$) and Samut Prakan ($R = 0.373$, $p<0.05$). Temperature correlated with the number of COVID-19 patients in eight provinces, that is Bangkok ($R = 0.430$, $p<0.05$), Chon Buri ($R = 0.264$, $p<0.05$), Nakhon Pathom ($R = 0.662$, $p<0.05$), Pathum Thani ($R = 0.343$, $p<0.05$), Ayutthaya ($R = 0.468$, $p<0.05$), Rayong ($R = 0.421$, $p<0.05$), Songkhla ($R = 0.253$, $p = 0.07$) and Samut Prakan ($R = 0.348$, $p<0.05$).

Table 3 shows the stepwise multiple regression that determined the association between the meteorological factor and the number of COVID-19 patients. The result showed that temperature significantly predicts the number of COVID-19 patients ($B = 22.097$, $R^2 = 0.037$, Adjusted $R^2 = 0.037$, $p<0.05$).

4. DISCUSSION

The results showed that overall cumulative COVID-19 patients in Thailand since January-May 2021 in Bangkok, Chiang Mai, Samut Prakan, and Chon Buri, which were among the areas with the highest number of COVID-19 patients, were 62,259 patients, 8,561 patients, 8,007 patients, and 5,766 patients, respectively. This result is consistent with the previous study that determined the relationship between population density and the number of COVID-19 patients in Thailand. The result showed that Bangkok, Samut Prakan, and Chon Buri have the highest number of COVID-19 cases (Ruksakulpiwat et al., 2022). Moreover, these three provinces are among the high population density areas (>124.9 people/km^2), significantly associated with the number of COVID-19 cases (Ruksakulpiwat et al., 2022).

Table 2. Correlation of the number of COVID-19 patients with meteorological factors by provinces

Province (number of COVID-19 patients)***	Correlation	Environmental factors			
		Relative humidity	Wind speed	Rainfall	Temperature
Bangkok (62,259 patients)	R	0.163	-0.127	0.133	0.430**
	p-value	0.07	0.16	0.14	0.00
Chachoengsao (2,222 patients)	R	0.131	-0.037	-0.203	0.260
	p-value	0.37	0.80	0.17	0.08
Chon Buri (5,766 patients)	R	0.212*	-0.159	0.151	0.264**
	p-value	0.02	0.09	0.10	0.00
Chiang Mai (8,561 patients)	R	-0.119	-0.067	-0.024	0.167
	p-value	0.41	0.64	0.86	0.24
Nakhon Pathom (1,543 patients)	R	-0.280*	-0.029	-0.012	0.662**
	p-value	0.01	0.79	0.91	0.00
Pathum Thani (4,671 patients)	R	0.041	0.203*	0.160	0.343**
	p-value	0.68	0.04	0.10	0.00
Prachuap Khiri Khan (1,868 patients)	R	0.220	0.036	0.198	-0.167
	p-value	0.13	0.80	0.18	0.26
Ayutthaya (1,349 patients)	R	0.215	-0.217	0.131	0.468**
	p-value	0.07	0.07	0.27	0.00
Rayong (1,282 patients)	R	-0.142	-0.034	-0.166	0.421**
	p-value	0.25	0.78	0.18	0.00
Songkhla (1,842 patients)	R	0.076	0.140	0.321*	0.253
	p-value	0.59	0.32	0.02	0.07
Samut Prakan (8,007 patients)	R	0.046	-0.423**	0.373**	0.348**
	p-value	0.63	0.00	0.00	0.00
Surat Thani (1,788 patients)	R	-0.070	-0.050	-0.087	0.251
	p-value	0.64	0.74	0.56	0.09
Total of 101,158 COVID-19 patients					

Note: *Correlation at the 0.01 level of significance.
**Correlation at the 0.05 level of significance.
***The number of patients in each province is the summation over the five months period.

Table 3. Regression analysis of the association between meteorological factors and the number of COVID-19 patients.

Factor	Unstandardized coefficient		Standardized coefficient	t	Significance	R^2	Adjusted R^2	Standard error of the estimate
	B	Standard error	Beta					
(Constant)	-568.963	291.846		-1.950	0.05	0.046	0.037	212.35401
Temperature	22.097	9.901	0.214	2.232	0.03			

Note: Dependent variable: number of COVID-19 patients (n = 101,158).

Accordingly, population density is associated with the ability to social distance (Rashed et al., 2020), which is an essential factor in COVID-19 transmission and the most effective prevention of disease transmission, particularly from asymptomatic individuals or those with mild, inconspicuous symptoms (Qian and Jiang, 2020). Also, contact rate may be heightened in regions with greater population density, such as large or metropolitan cities with high population density, which have a higher probability of coming into close contact with others. Therefore, stakeholders, like healthcare providers and policymakers, should introduce a sustainable strategy that encourages people to perform social distancing while typically spending their lives.

The data from January to May 2021 showed that the average relative humidity in the 12 provinces ranged from 80.43-95.42%, corresponding with the number of COVID-19 patients in the peak period. The previous study determined the influence of wind and relative humidity on the spread of COVID-19 infection (Feng et al., 2020). The result showed that COVID-19 transmission could be impacted by high relative humidity (Feng et al., 2020). Furthermore, another research demonstrated that humidity significantly associates with the spread of COVID-19 in a tropical climate (Auler et al., 2020). Regarding wind speeds, our result showed that the average wind speed was in the range of 1.76-4.99 m/s, a relatively low threshold, resulting in the possibility of the spread of COVID-19. This result is consistent with research on the effects of wind speed and air pollution on the accelerated transmission dynamics of COVID-19 (Coccia, 2021), which revealed that low wind speed could act as a carrier of COVID-19, facilitating the spread of COVID-19 in the environment.

Our study found that temperature was significantly associated with the number of COVID-19 patients. The previous study in India also found that the number of COVID-

19 patients significantly increased during summer when the temperature was higher than in other seasons (Sahoo et al., 2021a; Sahoo et al., 2021b). However, the negative correlation between temperature and the growth rate of the number of COVID-19 patients have shown in the studies conducted in China (Wu et al., 2020) and Bangladesh (Haque and Rahman, 2020). One possible explanation for this controversy is unusual behavior may be its irresistible nature. Unlike other viruses that cannot survive under extreme conditions (Basray et al., 2021), the SARS coronavirus has better stability in low temperature and humidity environments. Hence it may facilitate the transmission of the disease (Wu et al., 2020).

There were several restrictive measures that the Thai government was used to prevent the spread of COVID-19, for example, encouraging people to get vaccinations, working from home, and travel restrictions (Marome and Shaw, 2021; Srichannil, 2020; Ruksakulpiwat et al., 2021). Furthermore, the measure that the government used to manage the COVID-19 pandemic, the "Integrated Plan for Multilateral Cooperation for Safety and Mitigation of COVID-19", has been implemented by the Ministry of Public Health for the following objectives: (1) to reduce the chances of spreading the virus into Thailand, (2) to ensure Thai people are safe from COVID-19, (3) Alleviate the impacts on increased health, economic, social and national security (Oxford Policy Management and United Nations, 2020). It is suggested that integrating the meteorological factors contributing to the spread of COVID-19 should be considered in future policy measures.

5. CONCLUSION

This study aimed to determine the impact of meteorological factors on the number of COVID-19 patients in Thailand. The results showed that the meteorological factors impacted the number of COVID-19 patients differently. The meteorological factors in 12 provinces, including relative humidity, wind speed, and temperature, were significantly different. Furthermore, a significant association between temperature and the number of COVID-19 patients was found. The stepwise multiple regression showed that the temperature factor significantly predicted the number of COVID-19 patients. Therefore, the results could benefit further study aimed at determining a strategy to prevent the COVID-19 pandemic due to environmental factors, for example, developing and implementing an intervention to control meteorological factors that prevent the spread of COVID-19.

ACKNOWLEDGMENT

The authors would like to express thanks to the Department of Disease Control and Climatological Center of Thailand for this research dataset.

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APPENDIX

Supplementary Table S1. The difference in meteorological factors and the number of COVID-19 patients in 12 provinces

Factors	Results of one-way ANOVA test (*p*-value)
COVID-19 patients	0.00
Relative humidity	0.00
Wind speed	0.00
Rainfall	0.73
Temperature	0.00

Note: The level of significance at 0.05

Supplementary Table S2. The differences in the number of COVID-19 patients and meteorological factors in each province area

Factor	**Province**	**One-way ANOVA test, Scheffe method**													
		***p*-value**												**df**	**F**
		BKK	**CCO**	**CBI**	**CMI**	**NPI**	**PTE**	**PKN**	**AYA**	**RYG**	**SKA**	**SPA**	**SNI**		
COVID-19 patients	BKK	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Between Groups 11	19.633
	CCO	-	-	1.000	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Within Groups 1,083	
	CBI	-	-	-	0.961	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Total 1,094	
	CMI	-	-	-	-	0.871	0.956	0.969	0.881	0.892	0.966	0.994	0.975		
	NPT	-	-	-	-	-	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
	PTE	-	-	-	-	-	-	1.000	1.000	1.000	1.000	1.000	1.000		
	PKN	-	-	-	-	-	-	-	1.000	1.000	1.000	1.000	1.000		
	AYA	-	-	-	-	-	-	-	-	1.000	1.000	1.000	1.000		
	RYG	-	-	-	-	-	-	-	-	-	1.000	1.000	1.000		
	SKA	-	-	-	-	-	-	-	-	-	-	1.000	1.000		
	SPA	-	-	-	-	-	-	-	-	-	-	-	1.000		
	SNI	-	-	-	-	-	-	-	-	-	-	-	-		
Relative humidity	BKK	-	0.000	1.000	0.298	0.000	0.000	0.909	0.208	0.285	0.997	1.000	0.000	Between Groups 11	65.442
	CCO	-	-	0.000	0.000	1.000	0.686	0.000	0.000	0.000	0.000	0.000	0.999	Within Groups 1,500	
	CBI	-	-	-	0.019	0.000	0.000	1.000	0.811	0.878	1.000	1.000	0.000	Total 1,511	
	CMI	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.007	0.163	0.000		
	NPT	-	-	-	-	-	0.475	0.000	0.000	0.000	0.000	0.000	1.000		
	PTE	-	-	-	-	-	-	0.000	0.001	0.001	0.000	0.000	0.090		
	PKN	-	-	-	-	-	-	-	0.998	0.999	1.000	0.971	0.000		
	AYA	-	-	-	-	-	-	-	-	1.000	0.914	0.361	0.000		
	RYG	-	-	-	-	-	-	-	-	-	0.952	0.459	0.000		
	SKA	-	-	-	-	-	-	-	-	-	-	1.000	0.000		
	SPA	-	-	-	-	-	-	-	-	-	-	-	0.000		
	SNI	-	-	-	-	-	-	-	-	-	-	-	-		

Supplementary Table S2. The differences in the number of COVID-19 patients and meteorological factors in each province area (Continued)

Factor	Province	One-way ANOVA test, Scheffe method													
		p-value												df	F
		BKK	CCO	CBI	CMI	NPI	PTE	PKN	AYA	RYG	SKA	SPA	SNI		
Wind speed	BKK	-	0.975	0.011	0.995	1.000	1.000	0.930	0.000	1.000	0.034	0.000	0.996	Between Groups 11 Within Groups 1,497 Total 1,508	26.492
	CCO	-	-	0.000	1.000	1.000	0.555	0.093	0.000	0.686	0.000	0.000	1.000		
	CBI	-	-	-	0.000	0.000	0.215	0.766	0.083	0.139	1.000	0.995	0.000		
	CMI	-	-	-	-	1.000	0.730	0.186	0.000	0.835	0.000	0.000	1.000		
	NPT	-	-	-	-	-	0.897	0.375	0.000	0.950	0.000	0.000	1.000		
	PTE	-	-	-	-	-	-	1.000	0.000	1.000	0.392	0.002	0.746		
	PKN	-	-	-	-	-	-	-	0.000	0.999	0.906	0.068	0.198		
	AYA	-	-	-	-	-	-	-	-	0.000	0.030	0.795	0.000		
	RYG	-	-	-	-	-	-	-	-	-	0.280	0.001	0.847		
	SKA	-	-	-	-	-	-	-	-	-	-	0.972	0.000		
	SPA	-	-	-	-	-	-	-	-	-	-	-	0.000		
	SNI	-	-	-	-	-	-	-	-	-	-	-	-		
Temperature	BKK	-	0.015	0.967	0.000	0.000	1.000	0.005	0.892	0.010	0.018	0.651	0.004	Between Groups 11 Within Groups 1,500 Total 1,511	23.410
	CCO	-	-	0.711	0.962	0.000	0.115	1.000	0.866	1.000	1.000	0.979	1.000		
	CBI	-	-	-	0.013	0.000	0.999	0.530	1.000	0.643	0.740	1.000	0.490		
	CMI	-	-	-	-	0.000	0.000	0.991	0.040	0.977	0.953	0.151	0.994		
	NPT	-	-	-	-	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
	PTE	-	-	-	-	-	-	0.052	0.994	0.086	0.131	0.940	0.043		
	PKN	-	-	-	-	-	-	-	0.726	1.000	1.000	0.930	1.000		
	AYA	-	-	-	-	-	-	-	-	0.818	0.885	1.000	0.691		
	RYG	-	-	-	-	-	-	-	-	-	1.000	0.965	1.000		
	SKA	-	-	-	-	-	-	-	-	-	-	0.984	1.000		
	SPA	-	-	-	-	-	-	-	-	-	-	-	0.913		
	SNI	-	-	-	-	-	-	-	-	-	-	-	-		

Note: [1]Bangkok (BKK), Chachoengsao (CCO), Chon Buri (CBI), Chiang Mai (CMI), Nakhon Pathom (NPT), Pathum Thani (PTE), Prachuap Khiri Khan (PKN), Ayutthaya (AYA), Rayong (RYG), Songkhla (SKA), Samut Prakan (SPA), Surat Thani (SNI)
[2]The mean difference is significant at the 0.050 level.