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Research Article

Association of Air Pollutant Index (API) on SARS-CoV-2 of Coronavirus Disease 2019 (COVID-19) in Malaysia

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ABSTRACT Malaysia reported its first COVID-19 case on January 25, 2020, and the cases have continued to grow, necessitating the implementation of additional measures. Hence, determining the factors responsible for the significant increase in COVID-19 cases is the top priority issue for the government to take necessary action and ultimately restrain this virus before the vaccine availability. Researchers had predicted that air pollution had an indirect relationship with COVID-19 in terms of virus infections. As a result, this study focuses on the link between the Air Pollutant Index (API) and COVID-19 infections. The initial data set consists of daily confirmed COVID-19 cases in Malaysia and API readings obtained from the Ministry of Health (MOH) and the Department of the Environment (DOE). The results show that Klang (S22) recorded the highest mean of API which at 62.70 while the lowest is at Limbang (S37) (25.37). Next, due to the implementation of Movement Control Order (MCO) in Malaysia and reducing social movement, 27 stations recorded a good level of API compare to the stations that recorded moderate and unhealthy levels. There is positive relationship between API and COVID-19 at each of the region which are North 0.4% ($R^2=0.004$), Central 2.1% ($R^2=0.021$), South 0.04% ($R^2=0.0004$), East 1.6% ($R^2=0.016$), Sarawak 0.2% ($R^2=0.002$), meanwhile Sabah recorded negative correlation at 4.3% ($R^2=0.043$). To conclude, the API value did not have a strong relationship with the rising number of COVID-19 daily cases.

KEY WORDS COVID-19, Air pollutant index, Malaysia, Prevalence, Virus infection

1. INTRODUCTION

The progression of the disease is correlated with aspects such as older age, smoking habit, and the respiratory and cardiovascular diseases (Zhou *et al.*, 2020). High air pollutants concentration might induce and worsen the COVD-19 cases at certain area (Gupta *et al.*, 2020). The current global spread of SARS-CoV-2 coronavirus (COVID-19) began as a contagious event in the Chinese city of Wuhan in late December 2019 and erupted and was proclaimed a pandemic throughout Europe, the United States of America, and other parts of the world, including Malaysia, by March 2020. The disease was isolated from patients in Wuhan in early 2020 by the scientific community. The genetic sequencing of the new coronavirus has required real-time diagnostic tests to evolve rapidly (Wang *et al.*, 2020).

The first findings found that fever, cough, and myalgia are the most prevalent symptoms at the onset of the illness sputum development, headache and diarrhea were the less frequent symptoms (Cheng *et al.*, 2020; Sharma *et al.*, 2020; Wang *et al.*, 2020). The progression of the condition is associated with conditions such as old age, smoking history, elevated blood pressure, and heart disease (Gautam, 2020; Zhou *et al.*, 2020). The WHO announces the COVID-19 epidemic as a Public Health Emergency of International Concern due to its high degree of infectivity and its violent history, it has been granted pandemic status. Pneumonia infections transmitted by a novel coronavirus (COVID-19) is an infectious disease, with some similarity to previous infections documented over time such as Severe Acute Respiratory Syndrome (SARS-CoV) that occur on 2002–2003 and Middle East Respiratory Syndrome (MERS-CoV) that spread on 2012–2015 with some variations in its phenotypic and genotypic composition that may affect their pathogenic mechanisms.

Malaysia recorded the first COVID-19 cases on 25th January 2020 (Ministry of Health Malaysia, 2020). From thereon, the number of cases particularly in March 2020 has continued to increase. This rise of COVID-19 disease in Malaysia has called for a few steps to be taken, involve the development of a screening system to rapidly detect cases; cause of the symptoms urgent isolation and comprehensive surveillance of cases, and close contact quarantine for those tested positive for COVID-19. Intending to isolate the origins of the COVID-19 outbreak, the Malaysian Government declared the enforcement of the Movement Control Order (MCO). Human-to-human transmission between close contacts has occurred since mid-December 2019 and has steadily expanded over the upcoming month. On the other hand, optimizing air quality by minimizing both serious and long average concentrations will help protect cities from COVID-19 and reduce pressure on health facilities (Stieb *et al.*, 2020).

Exposure to air pollution had a very well association with heightened threats and severe effects of the spread of disease, including COVID-19, 2009 H1N1, and 1918 Spanish influenza pandemics (Clay *et al.*, 2019; Morales *et al.*, 2017). Exposure to criteria pollutants is known to cause respiratory and various other diseases that make people more vulnerable to infectious diseases close to COVID-19 (Mahnoor *et al.*, 2020). Latest reports have closely linked COVID-19 mortality to long-term exposure to air pollution in the United States (Shoari *et al.*, 2020). Among various controlling factors, environmental factors, especially air pollution play an essential role in the emergence of an influenza virus with pandemic potential. The severity of respiratory problems and lung infection will increase when there is a significant combination of air pollutant concentrations and virus infection at the same time. COVID-19 is a respiratory disease and particulate pollution is strongly linked with respiratory diseases. Air pollution is readily associated with respiratory infections such as chronic obstructive pulmonary disease (COPD). COVID-19 is mainly transmitted by droplets and contact. Aerosol transmission is possible when people have prolonged exposure to high concentrations of aerosols. Research has demonstrated that respiratory viruses are transmittable among individuals via contacting directly or indirectly, or coarse or small droplets and SARS-CoV-2 is transmittable through direct or indirectly salivary route (To *et al.*, 2020). Wong *et al.* (2010) denoted that the likelihood of transmitting influenza by aerosols could be reduced by improving ventilation design and prevention of generating aerosols. It is believed that transmitting by aerosols is plausible due to the high risk of cross-infection among physicians, nurses, and personnel (Hoseinzadeh *et al.*, 2017). Another study proved that the SARS-CoV-2 is probably transmitted via aerosols produce during therapeutic actions (Huang *et al.*, 2020). COVID-19 is spread by the airborne route. There are currently few studies that define the pathophysiological characteristics of COVID-19, and there is great uncertainty regarding its mechanism of spread. Current knowledge is largely derived from similar coronaviruses, which are transmitted from human-to-human through respiratory fomites. An epidemiological investigation of 198 early cases in Wuhan revealed that only 22% of patients had direct exposure to the marketplace, 32% were in contact with the suspected cases and 51% had no contact with either of the source (Ali *et al.*, 2020). However, the virus was capable of efficient human-to-human transmission, and similar to MERS, reports of nosocomial propagation were also documented (Ali *et al.*, 2020). This situation necessitated the need for the implementation of measures to abstain from transmissions. Thus, this study is aimed to investigate the association of Air Pollutant Index (API) towards COVID-19 infections in Malaysia.

2. METHODS

In Malaysia, the areas that reported COVID-19 were not in line with Air Quality Monitoring Station (AQMS). Thus, the nearest AQMS were taken to investigate the relationship between API with the reported COVID-19 confirmed cases (Table 1). Data of API have been collected from the Air Pollutant Index Malaysia (available at http://apims.doe.gov.my/public_v2/home.html) (DOE, 2021) and Malaysian Department of Environment from 18 March 2020 to 28 February 2021. The status of air quality in Malaysia is displayed on an hourly basis by the Malaysian Department of Environment (DOE) via the Air Pollutant Index (API). There are six criteria pollutants measured, including fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and ground-level ozone (O_3). Before the execution of API, the sub-index for each criteria pollutants are calculated, and the maximum sub-index is considered as the API, showing the status of air quality at that particular area. The monitoring was under the concession of DOE and Transwater Sdn. Bhd. which covers urban, suburban, industrial, and background stations (Ash'aari *et al.*, 2020). Most of the time, the sub-index of API was dominated by $PM_{2.5}$. Specifically, the $PM_{2.5}$ played an important role for Angiotensin-Converting Enzyme 2 (ACE2), but in order to represent the overall air quality status, the API is used as a representative for all pollutants. The exposure of high particulate matter will induce ACE2 expressions. ACE2 receptor usually exists at respiratory systems. The full-length protein structure of ACE2 consists of an N-terminal and a C-terminal domain with a single trans-membrane helix and an intracellular segment. ACE2 is expressed in different tissues, such as renal, cardiovascular, and gastrointestinal. ACE2 is also present in lung alveolar epithelial cells, enterocytes of the small intestine, arterial and venous endothelial cells, and arterial smooth muscle cells. ACE2 was previously identified as an entry receptor for SARS-CoV and HCoV-NL63. Higher expressions of ACE2 may prolong the virus life cycle, enhance virus replication and mediate penetration of the virus into the host cell. It has been reported that SARS-CoV-2 spike glycoprotein may use ACE2 as a receptor to gain entry into human cells, in a way similar to that of SARS-CoV. COVID-19 daily cases data have been acquired from the website of COVID-19 Malaysia (available at

Table 1. Selected AQMS in line with COVID-19 in Malaysia.

Region	State	Label	Stations
North	Perlis	S1	Kangar
	Kedah	S2	Langkawi
	Kedah	S3	Alor Setar
	Kedah	S4	Kulim Hi-Tech
	Pulau Pinang	S5	Seberang Perai
	Perak	S6	Taiping
	Perak	S7	Tasek Ipoh
	Perak	S8	Seri Manjung
East	Pahang	S9	Rompin
	Pahang	S10	Temerloh
	Pahang	S11	Jerantut
	Pahang	S12	Balok Baru Kuantan
	Terengganu	S13	Kemaman
	Terengganu	S14	Kuala Terengganu
	Terengganu	S15	Besut
	Kelantan	S16	Tanah Merah
	Kelantan	S17	Kota Bharu
Central	Kuala Lumpur	S18	Cheras
	Putrajaya	S19	Putrajaya
	Selangor	S20	Kuala Selangor
	Selangor	S21	Petaling Jaya
	Selangor	S22	Klang
South	Negeri Sembilan	S23	Seremban
	Negeri Sembilan	S24	Port Dickson
	Melaka	S25	Alor Gajah
	Melaka	S26	Bandaraya Melaka
	Johor	S27	Segamat
	Johor	S28	Batu Pahat
	Johor	S29	Kluang
	Johor	S30	Larkin
	Johor	S31	Kota Tinggi
	Johor	S32	Tangkak
Sabah		S33	Tawau
		S34	Sandakan
		S35	Kota Kinabalu
		S36	Keningau
Sarawak		S37	Limbang
		S38	Miri
		S39	Bintulu
		S40	Mukah
		S41	Kapit
		S42	Sibu
		S43	Sarikei
		S44	Sri Aman
		S45	Samarahan
		S46	Kuching

http://covid-19.moh.gov.my/) (MOH, 2021) from 18 March 2020 to 28 February 2021. Data in this study had been analyzed to determine the trend of API during the COVID-19 pandemic in Malaysia. These data were then translated into bar graph for clear observation regarding the trend. After getting the trend, the indication of air quality status at study areas is investigated. Descriptive statistics indices were evaluated (Abdullah *et al.*, 2020), and for the inferential statistics, it aims to correlate the relationship between API and COVID-19 cases using Microsoft Excel Spreadsheet® 2019.

3. RESULTS AND DISCUSSION

Table 2 summarizes the main statistical index which are minimum, maximum, median, average, standard deviation, variance, skewness, and kurtosis values of API based on AQMS in Malaysia. There are 46 locations of API at all-region in Malaysia that nearest to COVID-19 recorded areas (Fig. 1). Data have skewness ranged from −0.63 to 1.31 and kurtosis ranged −0.85 to 1.90. While for median are ranged from 23 to 61. Lastly, the range for standard deviation and variance are 7.25–18.74 and 52.55–351.10, respectively. The ranges of minimum to maximum API value for the North region (S1–S8), are from 2–97 while for the East (S9–S17), are from 8–139. Next, for Central (S18–S22) and South (S23–S32) are 17–116 and 8–124, respectively. Lastly, for Sabah (S33–S36) and Sarawak (S37–46) the range is between 9–71 and 8–90, respectively. In between this study period, Klang (S22) was found to be the most station-dominant air pollutant compared to others. The average API recorded was 62.70 and categorized as moderate according to the New Malaysian Ambient Air Quality Standard (NMAAQS). Since Port Klang is one of the industrial towns with a high volume of heavy vehicles (the monitoring site is also located just beside the main road of Port Klang), PM_{10} mass concentrations appear to accumulate in this area (Mohamad *et al.*, 2015). A study by Rahman *et al.* (2015) stated that air pollution sources in Klang are PM_{10}, and might has influence by relative humidity, and atmospheric temperature. This indicates that, in addition to CO and NO_2, PM_{10} was a significant air pollutant in the Klang Valley. The lowest API has been recorded at Limbang (S37) (25.37). Limbang is considered as the background station (rural). The distinct differences in NO_2, CO, and SO_2 variations revealed different origins for them. According to Zhou *et al.* (2020), the Rural Residential Coal Combustion (RRCC) for heating had a significant effect on air quality, adding 36.1, 9.1, and 16.1 percent of SO_2, NO_x, and $PM_{2.5}$ to the atmosphere, respectively, in the winter. According to the findings from Qiao *et al.* (2020), each 1 g/m^3 increase in PM_1, $PM_{2.5}$, PM_{10}, and NO_2 was linked to 14.9%, 14.6%, 7.3%, and 16.5% increased risk of osteoporosis, respectively. Air contamination in China's rural population is thought to be responsible for 20.29 to 24.36% of osteoporosis incidents. In Malaysia, cooking activity has led to a substantial increase in exposure from increasing concentrations in $PM_{2.5}$ during a COVID-19 lockdown (maximum average concentration at 52.2 $\mu g/m^3$) (Ezani *et al.*, 2020).

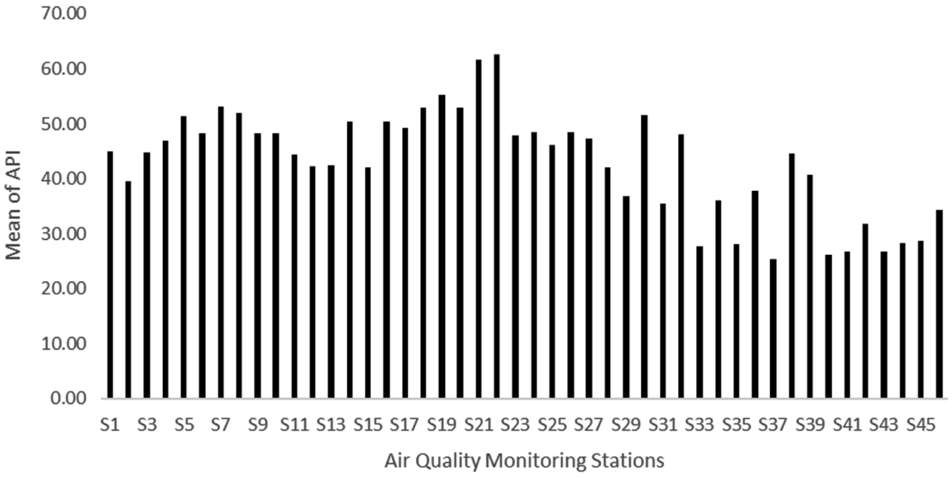

Fig. 1. The mean of API at Air Quality Monitoring Stations.

Table 2. Descriptive statistic of API based on Air Quality Monitoring Stations.

Region	State	Stations	AQMS	Min	Max	Mean	Med	Stdev	Var	Skew	Kurt
North	Perlis	S1	Kangar	13	97	44.92	47	13.28	176.24	−0.05	−0.37
	Kedah	S2	Langkawi	2	71	39.49	38	12.99	168.73	0.08	−1.11
	Kedah	S3	Alor Setar	15	96	44.81	47	15.01	225.16	0.12	−0.56
	Kedah	S4	Kulim Hi-Tech	15	79	46.89	51	12.77	163.07	−0.31	−0.75
	Pulau Pinang	S5	Seberang Perai	20	88	51.35	53	11.50	132.26	−0.30	−0.17
	Perak	S6	Taiping	11	88	48.33	52	13.88	192.56	−0.34	−0.34
	Perak	S7	Tasek Ipoh	21	87	53.06	54	10.57	111.73	−0.42	0.21
	Perak	S8	Seri Manjung	16	97	51.99	53	12.02	144.54	−0.08	0.45
East	Pahang	S9	Rompin	16	135	48.17	45	18.74	351.10	0.70	0.25
	Pahang	S10	Temerloh	10	91	48.29	52	13.21	174.47	−0.63	0.18
	Pahang	S11	Jerantut	8	79	44.33	47	13.87	192.37	−0.20	−0.85
	Pahang	S12	Balok Baru Kuantan	14	139	42.15	42	11.77	138.51	0.10	0.76
	Terengganu	S13	Kemaman	12	66	42.40	44	12.03	144.62	−0.51	−0.74
	Terengganu	S14	Kuala Terengganu	12	92	50.43	54	13.96	194.83	−0.54	0.56
	Terengganu	S15	Besut	11	78	41.96	43	13.46	181.26	−0.16	−0.78
	Kelantan	S16	Tanah Merah	10	98	50.48	53	15.28	233.39	−0.29	0.09
	Kelantan	S17	Kota Bharu	11	97	49.28	53	13.43	180.39	−0.41	0.38
Central	Kuala Lumpur	S18	Cheras	21	100	53.00	54	9.04	81.69	−0.74	1.14
	Putrajaya	S19	Putrajaya	22	116	55.15	55	9.65	93.09	−0.31	1.90
	Selangor	S20	Kuala Selangor	17	85	52.91	54	11.75	138.13	−0.46	0.17
	Selangor	S21	Petaling Jaya	27	112	61.70	60	10.87	118.14	0.49	1.04
	Selangor	S22	Klang	35	94	62.70	61	8.11	65.74	0.61	0.64
South	Negeri Sembilan	S23	Seremban	18	87	47.82	51	10.12	102.39	−0.48	−0.09
	Negeri Sembilan	S24	Port Dickson	21	124	48.39	51	10.44	108.94	−0.08	0.76
	Melaka	S25	Alor Gajah	18	80	46.04	49	12.51	156.58	−0.28	−0.83
	Melaka	S26	Bandaraya Melaka	16	101	48.36	51	10.74	115.30	−0.41	−0.31
	Johor	S27	Segamat	13	87	47.22	51	11.45	131.20	−0.71	0.13
	Johor	S28	Batu Pahat	12	89	42.07	44	13.39	179.17	−0.08	−0.53
	Johor	S29	Kluang	8	66	36.79	37	12.34	152.18	−0.08	−0.84
	Johor	S30	Larkin	21	101	51.46	53	9.55	91.22	−0.58	1.03
	Johor	S31	Kota Tinggi	10	74	35.36	33	11.45	131.06	0.44	−0.62
	Johor	S32	Tangkak	21	86	48.09	50	9.82	96.42	0.16	0.93
Sabah		S33	Tawau	10	63	27.77	27	7.25	52.55	0.80	1.81
		S34	Sandakan	14	60	35.94	35	8.79	77.22	0.11	−0.56
		S35	Kota Kinabalu	9	60	28.06	25	11.95	142.88	0.79	−0.39
		S36	Keningau	14	71	37.81	36	11.53	133.02	0.16	−1.13
Sarawak		S37	Limbang	9	60	25.37	23	9.88	97.54	1.22	1.31
		S38	Miri	17	90	44.59	47	11.57	133.88	−0.18	−0.57
		S39	Bintulu	13	74	40.67	41	12.62	159.29	−0.11	−1.05
		S40	Mukah	10	66	26.11	25	9.37	87.71	1.10	1.43
		S41	Kapit	9	67	26.68	25	7.81	60.99	1.28	2.61
		S42	Sibu	9	87	31.74	29	10.95	119.85	0.96	1.15
		S43	Sarikei	12	68	26.73	24	9.53	90.84	1.31	1.64
		S44	Sri Aman	8	84	28.32	25	11.33	128.30	1.05	1.16
		S45	Samarahan	11	66	28.62	27	10.26	105.30	1.02	0.65
		S46	Kuching	13	71	34.37	33	10.97	120.36	0.58	−0.34

Table 3 shows the percentage level of API in study areas. According to the Malaysian Department of Environment (2021), the API levels between 0 to 50 signified a good level. Good API shows that the study areas contain low pollution and do not impose negative health effects. No restrictions on public outdoor events, and encourages people to live a healthier lifestyle. The API level ranged from 51 to 100, indicating a moderate status. The areas were reported to have moderate emissions and no restrictions on outdoor activities. Finally, during the study, several locations reported an unhealthy level of API (101–200). Elderly, pregnant women, kids, and people with heart and lung problems suggested staying indoor and the government advises high-risk individuals to restrict their recreational behaviors. The good API level in the north area ranges from 30.12% to 70.81%. The highest percentage at Good was 70.81% in Langkawi (S2) (sub-urban), while the lowest percentage was in Tasek Ipoh (S7) (30.12%) (urban). In the East region. Balok Baru Kuantan (S12) (industrial) has the highest percentage (68.41%), while Kuala Terengganu (S11) (urban) has the lowest percentage (34.75%). Kuala Selangor (S20) (rural) had the highest percentage (30.78%) in the central area, while Klang (S22) (sub-urban) had the lowest percentage (2.41%). In the southern area, Kota Tinggi (S31) (sub-urban) recorded the highest percentage (83.86%) compared to Larkin (S30) (urban) that has the lowest percentage (32.12%). In Sabah, the percentage varies from 77.10 to 98.82%, with Tawau (S33) (sub-urban) being the most dominant (98.82%) at the good API level. Finally, in Sarawak, the good level of API ranges from 57.10% to 98.48%, with Kapit (S44) (rural) recording the highest percentages. In the North, the moderate API level ranged from 29.19% to 69.88%. Tasek Ipoh (S7) (urban) has the highest percentage, while Langkawi (S2) (sub-urban) has the lowest. In the East, Balok Baru Kuantan (S12) (Industrial) had the lowest percentage. The levels for central range from 75.09% to 97.59%. Cheras (S18) (urban), Putrajaya (S19) (sub-urban), Kuala Selangor (S20) (rural), Petaling Jaya (S21) (sub-urban), and Klang (S22) (sub-urban) were the study areas in this field. These areas in the region had an API rating of more than 50% at a moderate API level. At South, Larkin (S30) (urban) recorded the highest percentages in this region followed by Bandaraya Melaka (S26) (urban) that recorded 54.58%. Sabah and Sarawak were ranges from 1.18%–22.9% and 1.52%–42.9%, respectively. Keningau (S36) (background) and Miri (S38) (sub-urban) are recorded the highest percentages (22.9% & 42.9%) respectively. This study also revealed 0.6% and 0.08% from the east region for unhealthy API level located at Rompin (S9) (rural) and Balok Baru Kuantan (S12) (industrial) respectively. Next, at central region, Putrajaya (S19) (sub-urban) is recorded 0.11% while Petaling Jaya (S21) (sub-urban) recorded 0.17%. Lastly, at South, Port Dickson (S24) (sub-urban) produced 0.05% while Bandaraya Melaka (S26) (urban) and Larkin (S30) (urban) recorded only at 0.01% each.

Fig. 2 shows that recorded API at a good level is higher compared to a moderate level. This shows that better air quality is formed during the COVID-19 pandemic. Research from Abdullah *et al.* (2020) and Othman and Latif (2021) reported that the introduction of MCO greatly reduced human activities, resulting in lower air emissions and improved human health in Malaysia. Other than that, during the COVID-19 lockdown, Mahato *et al.* (2020) found a 36.84% decline in CO in the megacity of Delhi, which they attribute to closed highways, industrial factories, and power plants. A study by Rahman *et al.* (2021) stated that $PM_{2.5}$, NO_2, SO_2, O_3, and CO concentrations in Dhaka City decreased by 26%, 20.4%, 17.5%, 9.7%, and 8.8%, respectively during the partial and absolute lockdowns, respectively, relative to the time before the lockdown. The introduction of a lockout strategy to contain COVID-19 transmission was critical in lowering pollution levels. During the first partial lockdown, from March 1 to April 21, Baghdad's air quality index (AQI) improved by 13% relative to pre-lockdown levels. NO_2, $PM_{2.5}$, and PM_{10} concentrations in Baghdad decreased by 6%, 8%, and 15%, respectively but O_3 levels increased by 13% during the first partial and absolute lockdowns from March 1 to April 21. NO_2 and $PM_{2.5}$ levels fell by 20% and 2.5%, respectively, during the second partial lockout, which lasted from June 14 to July 24 while O_3 and PM_{10} levels increased by 525% and 56%, respectively (Hashim *et al.*, 2021). According to Wang *et al.* (2021), The air quality index (AQI) was decreased by 15.2%, and NO_2, PM_{10}, $PM_{2.5}$, and CO concentrations were reduced by 37.8%, 33.6%, 21.5%, and 20.4%, respectively. We discovered that traffic controls, especially the restriction of intra-city travel intensity (TI), had a major heterogeneous impact on NO_2, with a reduction of approximately 13.6%, and that any one-unit rise in control measures intensity decreased air pollution concentrations by approximately 2–4%.

Table 3. Percentage indication level of API at study areas.

Region	State	Station	AQMS	Good (0–50) (%) n = 207080	Moderate (51–100) (%) n = 142271	Unhealthy (101–200) (%) n = 79	Total (%)
North	Perlis	S1	Kangar	56.69	43.31	0	100
	Kedah	S2	Langkawi	70.81	29.19	0	100
	Kedah	S3	Alor Setar	55.60	44.4	0	100
	Kedah	S4	Kulim Hi-Tech	49.18	50.82	0	100
	Pulau Pinang	S5	Seberang Perai	37.08	62.92	0	100
	Perak	S6	Taiping	44.94	55.06	0	100
	Perak	S7	Tasek Ipoh	30.12	69.88	0	100
	Perak	S8	Seri Manjung	35.71	64.29	0	100
East	Pahang	S9	Rompin	58.80	40.59	0.60	100
	Pahang	S10	Temerloh	41.81	58.19	0	100
	Pahang	S11	Jerantut	56.40	43.60	0	100
	Pahang	S12	Balok Baru Kuantan	68.41	31.51	0.08	100
	Terengganu	S13	Kemaman	64.22	35.78	0	100
	Terengganu	S14	Kuala Terengganu	34.75	65.25	0	100
	Terengganu	S15	Besut	62.90	37.10	0	100
	Kelantan	S16	Tanah Merah	38.62	61.38	0	100
	Kelantan	S17	Kota Bharu	40.57	59.43	0	100
Central	Kuala Lumpur	S18	Cheras	24.91	75.09	0	100
	Putrajaya	S19	Putrajaya	20.41	79.48	0.11	100
	Selangor	S20	Kuala Selangor	30.78	69.22	0	100
	Selangor	S21	Petaling Jaya	7.85	91.98	0.17	100
	Selangor	S22	Klang	2.41	97.59	0	100
South	Negeri Sembilan	S23	Seremban	47.77	52.23	0	100
	Negeri Sembilan	S24	Port Dickson	46.43	53.52	0.05	100
	Melaka	S25	Alor Gajah	51.91	48.09	0	100
	Melaka	S26	Bandaraya Melaka	45.41	54.58	0.01	100
	Johor	S27	Segamat	47.15	52.85	0	100
	Johor	S28	Batu Pahat	65.30	34.70	0	100
	Johor	S29	Kluang	81.93	18.07	0	100
	Johor	S30	Larkin	32.12	67.87	0.01	100
	Johor	S31	Kota Tinggi	83.86	16.14	0	100
	Johor	S32	Tangkak	52.00	48.00	0	100
Sabah		S33	Tawau	98.82	1.18	0	100
		S34	Sandakan	92.83	7.17	0	100
		S35	Kota Kinabalu	91.12	8.88	0	100
		S36	Keningau	77.10	22.90	0	100
Sarawak		S37	Limbang	95.49	4.51	0	100
		S38	Miri	57.10	42.9	0	100
		S39	Bintulu	67.77	32.23	0	100
		S40	Mukah	97.02	2.98	0	100
		S41	Kapit	98.48	1.52	0	100
		S42	Sibu	90.35	9.65	0	100
		S43	Sarikei	95.98	4.02	0	100
		S44	Sri Aman	93.94	6.06	0	100
		S45	Samarahan	94.12	5.88	0	100
		S46	Kuching	88.76	11.24	0	100

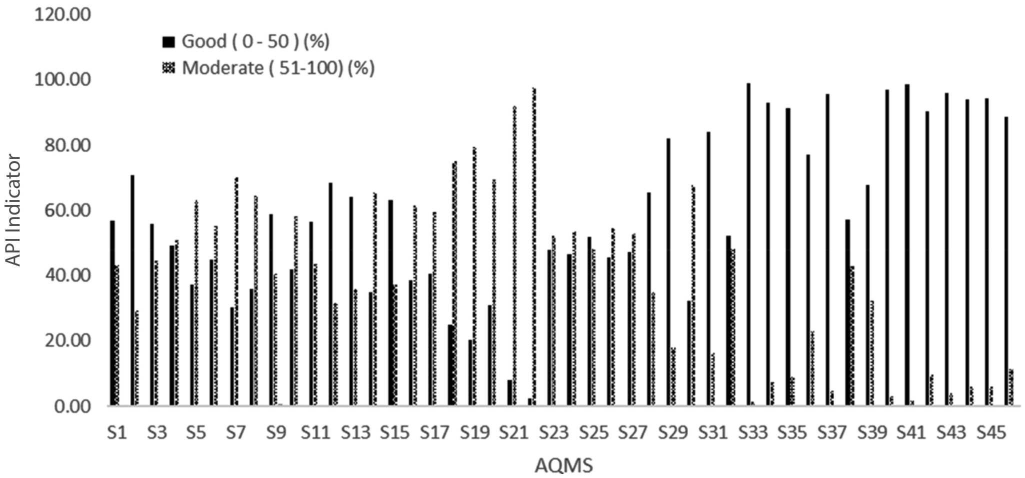

Fig. 2. Percentage of API Level at Air Quality Monitoring Stations.

Table 4. Summary of linear regression between API and COVID-19.

Region	Equation (y = mx + c)	R^2	p-value
North	C19 = 0.114 (API) + 2.054	0.004154	$p<0.05$
Central	C19 = 1.831 (API) − 45	0.021279	$p<0.05$
South	C19 = 0.102 (API) + 13	0.000412	$p>0.05$
East	C19 = 0.062 (API) + 0.227	0.015648	$p<0.05$
Sabah	C19 = −0.821 (API) + 71.56	0.043024	$p>0.05$
Sarawak	C19 = 0.065 (API) + 2.22	0.002565	$p<0.05$

According to Table 4 and Fig. 3, as the API variable increased by one unit, the number of COVID-19 cases increased by 0.114 in the north. In this region, the R^2 was only 0.4%. The number of COVID-19 cases increased by 1.831 in central areas as the API variable increased by one unit, resulting in a 2% of R^2. Following that, as the API variable increased by one unit, the COVID-19 cases increased by 0.102, resulting in a 0.04% R^2 in the south area. When the API variable was increased by one unit, the COVID-19 cases increased by 0.062 in the east. This area had an R^2 of 1.5%. Meanwhile, in Sabah, the number of COVID-19 cases decreased by 0.821 as the API value increased by one unit, resulting in a negative relationship with an R^2 of 4%. Finally, as the API value rose by one unit and R^2 was 0.2%, Sarawak recorded a 0.065 rise in COVID-19 cases. Based on the result, it is observed that there is a slight correlation between COVID-19 cases and API due to the exposure from the emission of industrialization activity, vehicle smoke, and road dust. We also can see that the ambient air did not contribute much to the rising of COVID-19 in Malaysia. Li *et al.* (2021) have also confirmed that the Air Quality Index (AQI) in China promotes the transmission of COVID-19 cases ($R^2=0.13$ and 0.223) in Wuhan and XiaoGan. Furthermore, in Milan, Italy, Zoran *et al.* (2020) have also justified that the COVID-19 new daily cases have positive significant relationship with the air quality index. In Singapore, it is reported that the pollutant standard index is also positively correlated with COVID-19 cases ($r=0.35$) (Lorenzo *et al.*, 2021). Moreover, several air pollutants concentration are positively correlated with COVID-19 cases in Mexico, which the evaluated correlation values are 0.77–0.80 (Tello-Leal and Macia-Hernandez, 2020). But, conversely, Sangkham *et al.* (2021) said that the daily confirmed COVID-19 cases are negatively associated with the air quality index in Bangkok ($r=0.458$), in line for Sabah region in this study. As advised by the MOH (2021), the community needs to practicing the 3W which are washing the hands using soap and sanitizer, wear the face mask when going outdoor, and warning from the government need to be alerted. Furthermore, the society also needs to avoid the 3C which mean close conversation, crowded place, and confined spaces to avoid the COVID-19 transmission from occurring. These actions had effective towards the society in curbing the COVID-19 spread. The spread of the COVID-19 outbreak is strongly associated with population movements in our culture, which may intensify the spread of novel coronaviruses and pose a serious threat to human life and public health (Wang *et al.*, 2021). The environmental factor like temperature might plays an important

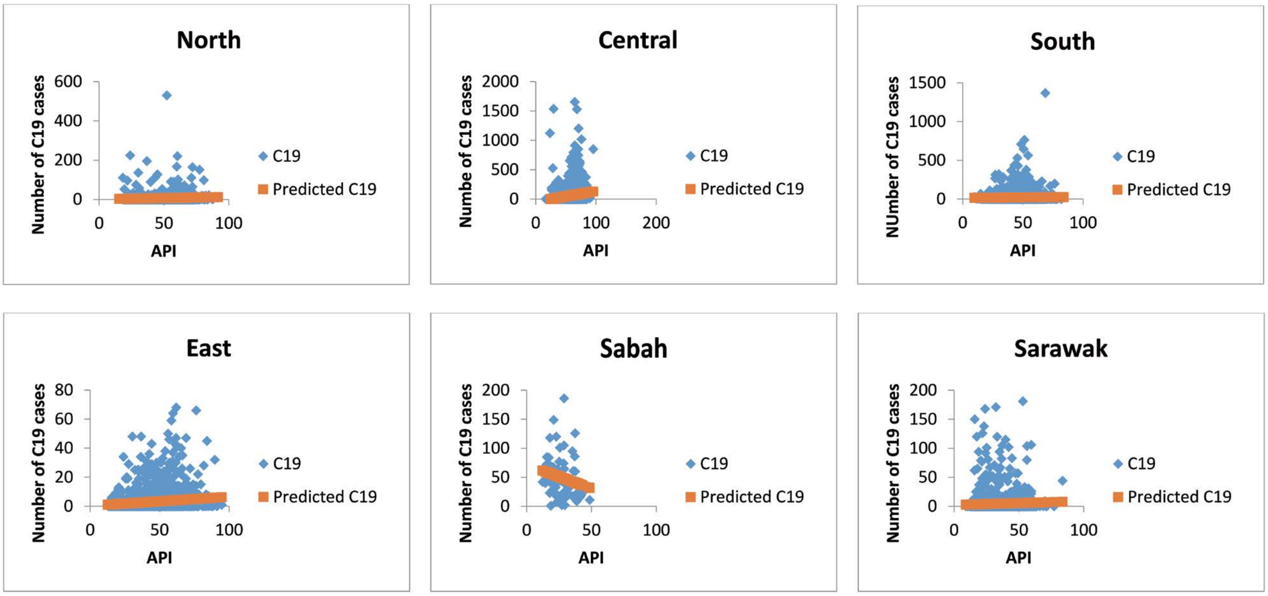

Fig. 3. The relationship of API and COVID-19.

role in the survival and transmission of viruses. Unusual temperature variation is an important risk factor for respiratory diseases. Temperature fluctuations can increase the mortality rate and enhanced influenza-related mechanisms. Influenza viruses live lengthier on surfaces or in droplets in cold and dry air, which increases the possibility of succeeding contagion (Hoseinzadeh *et al.*, 2020). Previously, the temperature is a significant factor influencing the infectious diseases such as SARS and influenza. Temperature and its changes affected the SARS outbreak (Lin *et al.*, 2006). Tan *et al.* (2005) found that the temperature was lower in the 2003 SARS outbreak and there is an increased risk of daily incidence. A study by Casanova *et al.* (2010) shows that the SARS-CoV strain of the infection was seen to endure longer on surfaces at a lower temperature. The SARS-CoV day by day rate of cases during the endemic was 18-overlap in lower temperatures contrasted with higher temperatures (Lin *et al.*, 2006). Furthermore, Chan *et al.* (2011) reported that the reasonability of different sorts of SARS Covids was diminished with high temperatures. Their study likewise recommends that tropical nations have a generally safe of SARS Covid disease as contrasted and moderately chilly nations. Higher temperatures have been shown to be protected against the transmission of the SARS in 2002–2003 (Lin *et al.*, 2006), perhaps because of the diminished endurance of the SARS-CoV on surfaces at higher temperatures (Chan *et al.*, 2011). For MERS-CoV, Gardner *et al.* (2019) found that it has a negative relationship among temperature and case occurrences for a situation case-crossover investigation. Unfortunately, Altamimi *et al.* (2019) found that the high temperature was one of the contributors to increased MERS-CoV cases. The speculation is drawn from the inverse relationship between warm temperature and viral infections, including influenza and other coronaviruses like MERS-CoV (Fagbo *et al.*, 2017; Lowen *et al.*, 2007).

Prata *et al.* (2020) examine the role of temperature on the combined number of COVID-19 cases in Brazil. The Generalized Additive Model (GAM) developed to reveal that there is an inverse relationship between temperature and daily cumulative COVID-19 cases. In-depth, they found that on every 1°C increase of temperature, will decrease 4.9% of COVID-19 cases in Brazil. Li *et al.* (2020) found that the daily temperature ($R^2 = 0.126$, $p < 005$) and daily lowest temperature ($R^2 = 0.143$, $p < 0.05$) were predominantly correlated with COVID-19 incidence, in inverse correlation by using simple linear regression analysis. Moreover, Mandal and Panwar (2020) found that the monthly average environment temperature has a strong negative correlation of total cases ($r = -0.45$), active cases ($r = -0.42$), and cases per million ($r = -0.50$) via Spearman correlation analysis. They added that a chilly climate might be an extra danger factor for COVID-19 cases. In Bangladesh, Haque and Rahman (2020) found that high temperature significantly reduces the transmission of COVID-19. They found the peak spread COVID-19 occurred at an average temperature of 26°C. In a study by Shahzad *et al.* (2020), the research found that there exists negative correlation between temperature and COVID-19 for several provinces; Guangdong ($r = -0.3038346$, $p < 0.05$), Henan ($r = -0.5006191$, $p < 0.05$), Jiangxi ($r = -0.5178269$, $p < 0.05$), Shandong ($r = -0.5246733$, $p < 0.05$), and Jiangsu ($r = -0.5211593$, $p < 0.05$), while some provinces show positive correlation; Hubei ($r = 0.5356257$, $p < 0.05$), Zhenjiang ($r = 0.4941642$, $p < 0.05$), Hunan ($r = 0.4372964$, $p < 0.05$), Anhui ($r = 0.5098245$, $p < 0.05$), and Heilongjiang ($r = 0.6612333$, $p < 0.05$). Xie and Zhu (2020) also used the GAM to determine the relationship between mean temperature and COVID-19 confirmed cases in China like Prata *et al.* (2020). Conversely, they found that mean temperature has a positive linear relationship with the number of COVID-19 cases over 122 cities when the temperature is below 3°C. For every 1°C increase is associated with a 4.861% increase in the daily number of COVID-19 confirmed cases. Menebo (2020) found that the maximum temperature ($r = 0.374$, $p < 0.05$) and normal temperature ($r = 0.293$, $p < 0.05$) were positively and significantly correlated with COVID-19. Azuma *et al.* (2020) revealed that COVID-19 is significantly associated with the increase in daily temperature or sunshine hours. This suggests that an increase in person-to-person contact due to increased outing activities on a warm and/or sunny day might promote the transmission of COVID-19. Interestingly, Runkle *et al.* (2020) stated that the temperature did not exhibit a strong association with COVID-19 in US cities. This is corroborated by To *et al.* (2021), who discovered no correlation between ambient temperature and COVID-19 incidence. The concept that lower or higher temperatures will limit COVID-19 transmission is not fully supported by various data. These contradictory findings regarding the effect of temperature on COVID-19 transmission emphasise the importance of conducting more investigation in a range of geographic areas and over long time periods. MOH (2020) also recorded that until November 2020, there are 119 clusters reported to be workplace-related. Of that number, a total of 36 clusters have been declared ended while another 83 clusters are still active to this day. A total of 77,201 individuals were screened in which a total of 12,079 cases were found to be COVID-19 positive. This involved 4,398 cases of citizens and 7,681 cases were non-citizens. This shows that the infection of COVID-19 is involved in the workplace that specifically in indoor spaces.

4. CONCLUSIONS

This research should ideally serve as a starting point for a better understanding of the factors affecting COVID-19 transmission and spread. Additionally, the findings imply that air quality should be prioritised, since it would help prevent the spread of infectious diseases such as COVID-19. Integrated solutions to avert pandemics comparable to COVID-19 should be developed not just in terms of medicine and wellness, but also in terms of sustainability and environmental science. Characterization of $PM_{2.5}$ is ideally a significant step in detecting the presence of SARS-CoV-2 genes in the air as the $PM_{2.5}$ has always dominated the API. Additional factors to consider include temperature, traffic volume, industrial activity, and biomass burning. Serious action must be done to halt the spread of COVID-19, with a particular emphasis on the installation of severe lockdowns that can significantly reduce the number of new confirmed cases of COVID-19 on a daily basis.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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