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Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-*n*CoV) pandemic

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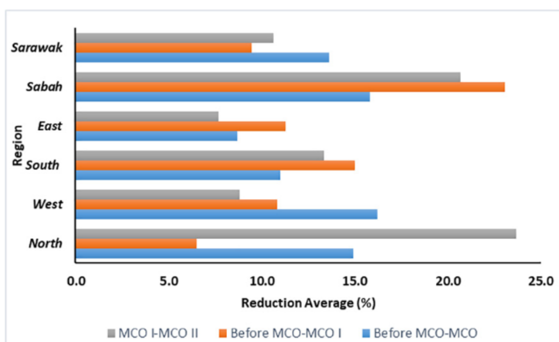
HIGHLIGHTS

- The $PM_{2.5}$ concentrations dominated the Air Pollutant Index (API) in Malaysia.
- There were several reductions on $PM_{2.5}$ concentrations during Malaysia Movement Control Order (MCO).
- Several red zone areas showed approximately 28.3% reduction of $PM_{2.5}$ concentrations.
- The Northern Region of Peninsular Malaysia showed the highest average reduction of $PM_{2.5}$ concentrations, with 23.7%.

GRAPHICAL ABSTRACT



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ABSTRACT

An outbreak of respiratory illness which is proven to be infected by a 2019 novel coronavirus (2019-*n*CoV) officially named as Coronavirus Disease 2019 (COVID-19) was first detected in Wuhan, China and has spread rapidly in other parts of China as well as other countries around the world, including Malaysia. The first case in Malaysia was identified on 25 January 2020 and the number of cases continue to rise since March 2020. Therefore, 2020 Malaysia Movement Control Order (MCO) was implemented with the aim to isolate the source of the COVID-19 outbreak. As a result, there were fewer number of motor vehicles on the road and the operation of industries was suspended, ergo reducing emissions of hazardous air pollutants in the atmosphere. We had acquired the Air Pollutant Index (API) data from the Department of Environment Malaysia on hourly basis before and during the MCO with the aim to track the changes of fine particulate matter ($PM_{2.5}$) at 68 air quality monitoring stations. It was found that the $PM_{2.5}$ concentrations showed a high reduction of up to 58.4% during the MCO. Several red zone areas (>41 confirmed COVID-19 cases) had also reduced of up to 28.3% in the $PM_{2.5}$ concentrations variation. The reduction did not solely depend on MCO, thus the researchers suggest a further study considering the influencing factors that need to be adhered to in the future.

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1. Introduction

Coronavirus is one of the significant pathogens that affects human respiratory system. Coronavirus Disease 2019 (COVID-19) is caused by a novel CoV, namely severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which is formerly known as 2019 novel coronavirus (2019-*n*CoV) (H. Li et al., 2020). The outbreak of SARS-CoV-2 began at Wuhan, Hubei Province, People's Republic of China in late December 2019 (Q. Li et al., 2020). Considering the global threat, the World Health Organization (WHO) has declared COVID-19 as a Public Health Emergency of International Concern (PHEIC) (Sohrabi et al., 2020). It is a pandemic that is spreading in other parts of Asia, such as Japan, Thailand, Singapore, Malaysia, and Australia as well as Europe and North America (Rothan and Byrareddy, 2020). Older people with the age of >80 years old has a high mortality susceptibility, with the case-fatality rate of 21.9% once infected with COVID-19 (Koh and Hoeing, 2020). In Malaysia, the earliest COVID-19 cases were detected on 25 January 2020 (Ministry of Health Malaysia, 2020). The number of cases have since then kept on increasing, especially in March 2020. This escalating COVID-19 outbreak in Malaysia has urged several measures to be taken, including putting surveillance system in place to detect cases immediately; carrying out rapid diagnosis; performing immediate case isolation and rigorous tracking; and quarantining close contacts of those who have been tested positive in COVID-19. Malaysian government has announced the implementation of Movement Control Order (MCO) with the aim to isolate the source of the COVID-19 outbreak. Statistically, the number of confirmed COVID-19 cases at the end of Phase I MCO is 2766 cases (31 March 2020) and for Phase II is 4987 cases (14 April 2020) (Ministry of Health Malaysia, 2020). During MCO, several activities, including operating business is not allowed, except for essential services (Malaysian National Security Council (NSC), 2020). Since people are working from home and several industries are suspended, the traffic density and industrial emissions have reduced. In Malaysia, the sources of air pollution are derived from motor vehicles, industrial emissions, and open burning (Latif et al., 2014; Abdullah et al., 2019). The air quality status is defined based on the Air Pollutant Index (API) of 6 criteria pollutants whereby the dominant pollutant in Malaysia is fine particulate matter ($PM_{2.5}$). Therefore, in this study, the researchers will evaluate the variation of $PM_{2.5}$ changes during and before MCO in Malaysia.

2. Methods

In Malaysia, the air quality is managed by the Department of Environment under the Ministry of Environment and Water. The researchers acquired the Air Pollutant Index (API) data from the website of Air Pollutant Index of Malaysia (available at http://apims.doe.gov.my/public_v2/home.html) on hourly basis from 14 March 2020 to 14 April 2020 to determine the relative changes (%) of air quality. These data covered the air quality status before MCO (14–17 March 2020) ($n = 6445$), during Phase I MCO (18–31 March 2020) ($n = 22{,}848$) and Phase II MCO (1–14 April 2020) ($n = 22{,}835$). Overall, there are 0.19% of missing data and the total data used in this study is 55,128. The missing data were omitted in this study. The API for each hour was then converted to $PM_{2.5}$ concentrations ($\mu g/m^3$) (available at http://apims.doe.gov.my/public_v2/aboutapi.html). The computation of API and $PM_{2.5}$ concentrations is shown in Table 1.

All 68 air quality monitoring stations in Malaysia were selected in this study, as shown in Table 2. The stations are responsible of monitoring the air quality status in Malaysia comprehensively (available at http://apims.doe.gov.my/public_v2/aboutapi.html) to detect any significant changes in the environment quality that may be harmful to human health and the environment (Department of Environment Malaysia, 2020).

Table 1
Computation of API and $PM_{2.5}$ concentration.

API	Breakpoint of concentration	Equation for API
$X = PM_{2.5}$ (24 h average, unit: $\mu g/m^3$)		
0–50	$0 \le X \le 12.0$	$API = 4.1667 * X$
51–100	$12.1 \le X \le 75.5$	$API = 0.7741 * (X - 12.1) + 51$
101–200	$75.5 \le X \le 150.4$	$API = 1.3218 * (X - 75.5) + 101$
201–300	$150.5 \le X \le 250.4$	$API = 0.9909 * (X - 150.5) + 201$
301–400	$250.4 \le X \le 350.4$	$API = 0.9909 * (X - 250.5) + 301$
401–500	$350.5 \le X \le 500.4$	$API = 0.6604 * (X - 350.5) + 401$

∗ is multiply.

3. Results and discussion

The MCO has been found to reduce $PM_{2.5}$ concentrations. Before the implementation of MCO and during the MCO (18 March–14 April 2020), the daily $PM_{2.5}$ concentrations were in the range of 5.3–42.5 $\mu g/m^3$ and 3.9–69.2 $\mu g/m^3$, respectively. The New Malaysia Ambient Air Quality Standard (NMAAQS) has set the standard limit of $PM_{2.5}$ to 35 $\mu g/m^3$ for a 24-hour average (Department of Environment Malaysia, 2020) and the World Health Organization (WHO) (2017) has set a more stringent limit of $PM_{2.5}$ to 25 $\mu g/m^3$. Before MCO, one of the air quality monitoring stations that exceeded the limit was Politeknik Kota Kinabalu (S55) (42.5 $\mu g/m^3$), while during MCO, the $PM_{2.5}$ concentrations at Rompin (S38) exceeded the limit of NMAAQS with 69.2 $\mu g/m^3$. Table 3 shows the variation of daily $PM_{2.5}$ concentrations before and during MCO. The reduction of $PM_{2.5}$ concentrations occurred at 34 stations, which attributed for 50% of overall stations. The highest reduction was at Politeknik Kota Kinabalu (S55), with 58.5% (Before = 41.2 $\mu g/m^3$; During MOC = 17.1 $\mu g/m^3$), while the lowest reduction was at Miri (S58), with 0.6% (reduce at 0.1 $\mu g/m^3$). Table 4 shows the variation of daily $PM_{2.5}$ concentrations before and during MCO I. The reduction of $PM_{2.5}$ concentrations occurred at 29 stations, which attributed for 42.6% of overall stations. The highest reduction was at Politeknik Kota Kinabalu (S55), with 53.6% (Before = 41.2 $\mu g/m^3$; MCO *I* = 19.1 $\mu g/m^3$), while the lowest reduction was at Mindin (S8), with 0.8% (Before = 19.6 $\mu g/m^3$; During MCO *I* = 19.7 $\mu g/m^3$). Table 5 shows the variation of daily $PM_{2.5}$ concentrations during MCO I and MCO II. Interestingly, the reduction of $PM_{2.5}$ concentrations occurred at 52 stations, which attributed for 76.5% of overall stations. The highest reduction was at Seberang Perai (S7), with 35.1% (MCO *I* = 21.1 $\mu g/m^3$; MCO II = 13.7 $\mu g/m^3$), while the lowest reduction was at Mindin (S8), with 0.3% (reduce at 0.1 $\mu g/m^3$). Fig. 1 shows the reduction average of $PM_{2.5}$ based on different regions in Peninsular Malaysia (North, Central, South, East) and the East Malaysia of Sabah and Sarawak. High reductions were found in Peninsular Malaysia at the North (23.7%), Central (16.2%), South (15%), and East (11.3%) regions as well as the East Malaysia of Sabah (23.1%) and Sarawak (13.6%) at a different timeline before MCO, during MCO I and MCO II. The ranges of reduction were 6.5–23.7%, 8.8–16.2%, 11.0–13.3%, 7.7–11.3%, 15.8–23.1%, 9.5–13.6% for North, Central, South, and East of Peninsular Malaysia, followed by the East Malaysia of Sabah and Sarawak, respectively.

The MCO in Malaysia included several prohibitions of mass movement and gathering; Malaysians travelling abroad; tourists and visitors' entry; and educational institutions, government and private agencies (except for essential services) closure (Malaysian National Security Council (NSC), 2020). These restrictions indirectly reduce the air pollution in Malaysia, although a detailed study needs to be conducted by considering other influencing factors, including local meteorology and anthropogenic emissions. Based on the results, the MCO had successfully reduced pollutants emission, particularly $PM_{2.5}$ concentrations, as there were less motor vehicles and industry activities during the MCO. There were several red zone areas with >41 cases of confirmed COVID-19 (Crisis Preparedness and Response Centre, 2020). Some red zone areas were then enforced under the Enhanced Movement Control

Table 2
Air quality monitoring stations in Malaysia.

Station	Region	State	Location
S1	North	Perlis	Kangar
S2		Kedah	Langkawi
S3		Kedah	Alor Setar
S4		Kedah	Sungai Petani
S5		Kedah	Kulim Hi-Tech
S6		Pulau Pinang	Seberang Jaya
S7		Pulau Pinang	Seberang Perai
S8		Pulau Pinang	Minden
S9		Pulau Pinang	Balik Pulau
S10		Perak	Taiping
S11		Perak	Tasek Ipoh
S12		Perak	Pegoh Ipoh
S13		Perak	Seri Manjung
S14		Perak	Tanjung Malim
S15	Central	Kuala Lumpur	Batu Muda
S16		Kuala Lumpur	Cheras
S17		Putrajaya	Putrajaya
S18		Selangor	Kuala Selangor
S19		Selangor	Petaling Jaya
S20		Selangor	Shah Alam
S21		Selangor	Klang
S22		Selangor	Banting
S23		Selangor	Johan Setia Klang
S24	South	Negeri Sembilan	Nilai
S25		Negeri Sembilan	Seremban
S26		Negeri Sembilan	Port Dickson
S27		Melaka	Alor Gajah
S28		Melaka	Bukit Rambai
S29		Melaka	Bandaraya Melaka
S30		Johor	Segamat
S31		Johor	Batu Pahat
S32		Johor	Kluang
S33		Johor	Larkin
S34		Johor	Pasir Gudang
S35		Johor	Pengerang
S36		Johor	Kota Tinggi
S37		Johor	Tangkak
S38	East	Pahang	Rompin
S39		Pahang	Temerloh
S40		Pahang	Jerantut
S41		Pahang	Indera Mahkota Kuantan
S42		Pahang	Balok Baru Kuantan
S43		Terengganu	Kemaman
S44		Terengganu	Paka
S45		Terengganu	Kuala Terengganu
S46		Terengganu	Besut
S47		Kelantan	Tanah Merah
S48		Kelantan	Kota Bharu
S49	Sabah	Sabah	Tawau
S50		Sabah	Sandakan
S51		Sabah	Kota Kinabalu
S52		Sabah	Kimanis
S53		Sabah	Keningau
S54		Labuan	Labuan
S55		Sabah	Politeknik Kota Kinabalu
S56	Sarawak	Sarawak	Limbang
S57		Sarawak	ILP Miri
S58		Sarawak	Miri
S59		Sarawak	Samalaju
S60		Sarawak	Bintulu
S61		Sarawak	Mukah
S62		Sarawak	Kapit
S63		Sarawak	Sibu
S64		Sarawak	Sarikei
S65		Sarawak	Sri Aman
S66		Sarawak	Samarahan
S67		Sarawak	Kuching
S68		Sarawak	IPD Serian

Table 3
Variation of daily $PM_{2.5}$ concentrations before MCO and during MCO.

Location	Before MCO	During MCO	Variation	
			μg/m^3	%
Kangar	11.3	12.6	1.3	+11.8
Langkawi	11.7	12.4	0.7	+6.3
Alor Setar	15.4	16.8	1.3	+8.7
Sungai Petani	20.8	18.2	−2.6	−12.5
Kulim Hi-Tech	20.0	15.7	−4.3	−21.5
Seberang Jaya	21.6	21.0	−0.6	−2.9
Seberang Perai	19.2	17.4	−1.8	−9.4
Minden	19.7	16.2	−3.5	−17.7
Balik Pulau	19.3	20.3	1.0	+5.2
Taiping	20.3	16.4	−3.9	−19.2
Tasek Ipoh	20.9	17.7	−3.2	−15.2
Pegoh Ipoh	18.3	18.7	0.5	+2.5
Seri Manjung	21.2	17.7	−3.5	−16.3
Tanjung Malim	11.5	9.3	−2.3	−19.7
Batu Muda	16.9	18.8	1.9	+11.4
Cheras	14.4	15.7	1.4	+9.4
Putrajaya	15.0	17.6	2.5	+16.9
Kuala Selangor	18.8	15.5	−3.3	−17.5
Petaling Jaya	22.1	16.7	−5.4	−24.3
Shah Alam	18.5	17.3	−1.3	−6.8
Klang	19.5	22.0	2.5	+13.0
Banting	12.6	15.0	2.4	+18.7
Nilai	14.1	15.8	1.7	+11.8
Seremban	10.1	12.0	1.9	+18.9
Port Dickson	11.2	13.8	2.6	+23.0
Alor Gajah	8.9	10.9	2.0	+22.8
Bukit Rambai	12.4	13.0	0.6	+4.8
Bandaraya Melaka	11.0	13.3	2.3	+20.6
Segamat	14.0	18.9	4.9	+34.8
Batu Pahat	9.4	11.7	2.2	+23.9
Kluang	9.1	9.6	0.5	+5.0
Larkin	13.6	13.9	0.3	+2.0
Pasir Gudang	9.3	10.9	1.6	+17.1
Pengerang	8.0	14.5	6.5	+82.1
Kota Tinggi	8.1	7.2	−0.9	−11.0
Tangkak	12.6	13.7	1.1	+8.8
Rompin	8.6	19.2	10.5	+122.4
Temerloh	12.4	14.1	1.7	+13.6
Jerantut	12.5	12.9	0.3	+2.7
Indera Mahkota Kuantan	8.5	8.8	0.2	+2.9
Balok Baru Kuantan	10.3	9.6	−0.7	−7.0
Kemaman	14.8	12.6	−2.3	−15.2
Paka	8.7	9.2	0.5	+5.8
Kuala Terengganu	13.3	17.0	3.8	+28.3
Besut	11.0	13.3	2.3	+21.0
Tanah Merah	23.8	22.9	−0.9	−3.9
Kota Bharu	12.0	18.8	6.8	+57.0
Tawau	8.7	7.2	−1.6	−17.8
Sandakan	12.2	10.0	−2.2	−18.3
Kota Kinabalu	13.7	11.7	−2.0	−14.3
Kimanis	22.5	13.7	−8.8	−39.0
Keningau	12.5	11.9	−0.6	−4.7
Labuan	14.9	14.8	−0.1	−0.8
Limbang	11.3	9.4	−1.9	−16.6
ILP Miri	20.5	18.5	−2.0	−9.9
Miri	12.0	12.0	−0.1	−0.6
Samalaju	13.0	12.0	−1.0	−8.1
Bintulu	13.9	13.5	−0.3	−2.4
Mukah	7.7	7.3	−0.3	−4.2
Kapit	7.4	6.8	−0.6	−8.4
Sibu	11.3	9.5	−1.8	−15.9
Sarikei	9.0	7.1	−1.9	−21.3
Sri Aman	8.1	7.8	−0.3	−3.8
Samarahan	8.1	8.6	0.5	+6.5
Kuching	8.9	9.8	0.9	+10.4
Johan Setia Klang	41.9	29.1	−12.8	−30.6
IPD Serian	5.4	7.0	1.6	+29.4
Politeknik Kota Kinabalu	41.2	17.1	−24.1	−58.5

Order (EMCO). The red zone areas included Kluang (S32) (28.3% reduction of $PM_{2.5}$ concentrations, MCO I and MCO II), Jerantut (S40) (14.5%, MCO I and MCO II), Kota Bharu (S48) (0.3%, MCO I and MCO II), Petaling Jaya (S19) (24.3%, before and during MCO), Klang (S21) (11.5%, MCO I and MCO II), Cheras (S16) (4.9%, MCO I and MCO II), Seremban (S25) (11.6%, MCO I and MCO II), Bandaraya Melaka (S29) (9.6%, MCO I and MCO II), Tawau (S49) (25.1%, before and during MCO I), Kuching (S67) (0.9%, before and during MCO I), and Samarahan (S66) (11.2%, before and during MCO I). The researchers observed that the decreasing of

Table 4
Variation of daily $PM_{2.5}$ concentrations before MCO and MCO I.

Location	Before MCO	MCO I	Variation	
			μg/m³	%
Kangar	11.3	13.2	1.9	+17.2
Langkawi	11.7	12.9	1.3	+10.9
Alor Setar	15.4	20.2	4.7	+30.7
Sungai Petani	20.8	21.1	0.3	+1.4
Kulim Hi-Tech	20.0	18.6	−1.3	−6.7
Seberang Jaya	21.6	25.4	3.8	+17.6
Seberang Perai	19.2	21.1	1.9	+9.9
Minden	19.7	19.6	−0.1	−0.8
Balik Pulau	19.3	23.6	4.2	+22.0
Taiping	20.3	19.1	−1.2	−6.0
Tasek Ipoh	20.9	20.1	−0.8	−3.9
Pegoh Ipoh	18.3	19.2	1.0	+5.3
Seri Manjung	21.2	18.8	−2.4	−11.3
Tanjung Malim	11.5	10.3	−1.2	−10.2
Batu Muda	16.9	19.1	2.2	+13.1
Cheras	14.4	16.1	1.7	+12.1
Putrajaya	15.0	18.0	2.9	+19.4
Kuala Selangor	18.8	17.6	−1.2	−6.2
Petaling Jaya	22.1	17.2	−4.9	−22.0
Shah Alam	18.5	17.7	−0.8	−4.3
Klang	19.5	23.4	3.9	+19.9
Banting	12.6	15.9	3.3	+25.9
Nilai	14.1	16.3	2.1	+15.2
Seremban	10.1	12.8	2.7	+26.2
Port Dickson	11.2	15.0	3.8	+33.4
Alor Gajah	8.9	11.3	2.4	+27.4
Bukit Rambai	12.4	13.1	0.7	+5.5
Bandaraya Melaka	11.0	13.9	2.9	+26.7
Segamat	14.0	17.3	3.3	+23.2
Batu Pahat	9.4	11.5	2.1	+22.2
Kluang	9.1	11.1	2.0	+22.3
Larkin	13.6	14.4	0.8	+5.8
Pasir Gudang	9.3	10.8	1.5	+16.3
Pengerang	8.0	17.1	9.1	+115.0
Kota Tinggi	8.1	6.9	−1.2	−15.0
Tangkak	12.6	14.9	2.3	+18.2
Rompin	8.6	17.3	8.7	+100.6
Temerloh	12.4	14.6	2.2	+17.6
Jerantut	12.5	13.9	1.3	+10.7
Indera Mahkota Kuantan	8.5	8.9	0.3	+4.0
Balok Baru Kuantan	10.3	9.9	−0.4	−4.0
Kemaman	14.8	12.8	−2.0	−13.8
Paka	8.7	8.4	−0.3	−3.7
Kuala Terengganu	13.3	18.8	5.5	+41.7
Besut	11.0	12.5	1.5	+13.6
Tanah Merah	23.8	24.0	0.2	+0.8
Kota Bharu	12.0	18.8	6.9	+57.3
Tawau	8.7	6.5	−2.2	−25.1
Sandakan	12.2	9.0	−3.3	−26.6
Kota Kinabalu	13.7	13.1	−0.6	−4.6
Kimanis	22.5	16.1	−6.4	−28.4
Keningau	12.5	12.6	0.1	+0.4
Labuan	14.9	16.6	1.7	+11.4
Limbang	11.3	9.2	−2.1	−18.5
ILP Miri	20.5	21.2	0.6	+3.1
Miri	12.0	12.7	0.7	+5.5
Samalaju	13.0	12.1	−0.9	−7.3
Bintulu	13.9	13.7	−0.2	−1.1
Mukah	7.7	7.4	−0.3	−3.4
Kapit	7.4	6.3	−1.1	−14.5
Sibu	11.3	10.6	−0.7	−6.0
Sarikei	9.0	7.0	−2.0	−22.1
Sri Aman	8.1	7.3	−0.8	−9.5
Samarahan	8.1	7.2	−0.9	−11.2
Kuching	8.9	8.8	−0.1	−0.9
Johan Setia Klang	41.9	32.0	−9.9	−23.6
IPD Serian	5.4	6.9	1.5	27.2
Politeknik Kota Kinabalu	41.2	19.1	−22.1	−53.6

Table 5
Variation of daily $PM_{2.5}$ concentrations during MCO I and MCO II.

Location	MCO I	MCO II	Variation	
			μg/m³	%
Kangar	13.2	12.0	−1.2	−9.3
Langkawi	12.9	11.9	−1.1	−8.3
Alor Setar	20.2	13.4	−6.8	−33.6
Sungai Petani	21.1	15.3	−5.8	−27.5
Kulim Hi-Tech	18.6	12.7	−5.9	−31.8
Seberang Jaya	25.4	16.6	−8.8	−34.8
Seberang Perai	21.1	13.7	−7.4	−35.1
Minden	19.6	12.9	−6.7	−34.1
Balik Pulau	23.6	17.1	−6.5	−27.5
Taiping	19.1	13.7	−5.4	−28.1
Tasek Ipoh	20.1	15.4	−4.7	−23.6
Pegoh Ipoh	19.2	18.2	−1.0	−5.2
Seri Manjung	18.8	16.7	−2.1	−11.2
Tanjung Malim	10.3	8.2	−2.2	−21.1
Batu Muda	19.1	18.5	−0.6	−3.0
Cheras	16.1	15.4	−0.8	−4.9
Putrajaya	18.0	17.2	−0.7	−4.2
Kuala Selangor	17.6	13.3	−4.3	−24.3
Petaling Jaya	17.2	16.2	−1.0	−5.8
Shah Alam	17.7	16.8	−0.9	−5.2
Klang	23.4	20.7	−2.7	−11.5
Banting	15.9	14.0	−1.8	−11.5
Nilai	16.3	15.3	−1.0	−5.9
Seremban	12.8	11.3	−1.5	−11.6
Port Dickson	15.0	12.6	−2.3	−15.7
Alor Gajah	11.3	10.5	−0.8	−7.1
Bukit Rambai	13.1	12.9	−0.2	−1.5
Bandaraya Melaka	13.9	12.6	−1.3	−9.6
Segamat	17.3	20.5	3.2	+18.8
Batu Pahat	11.5	11.8	0.3	+2.9
Kluang	11.1	8.0	−3.2	−28.3
Larkin	14.4	13.4	−1.0	−7.2
Pasir Gudang	10.8	11.0	0.2	+1.5
Pengerang	17.1	11.9	−5.2	−30.6
Kota Tinggi	6.9	7.5	0.6	+9.3
Tangkak	14.9	12.5	−2.4	−15.9
Rompin	17.3	21.0	3.8	+21.7
Temerloh	14.6	13.6	−1.0	−6.8
Jerantut	13.9	11.9	−2.0	−14.5
Indera Mahkota Kuantan	8.9	8.7	−0.2	−2.1
Balok Baru Kuantan	9.9	9.3	−0.6	−6.1
Kemaman	12.8	12.4	−0.4	−3.2
Paka	8.4	10.0	1.7	+19.8
Kuala Terengganu	18.8	15.3	−3.6	−19.0
Besut	12.5	14.1	1.6	+12.9
Tanah Merah	24.0	21.8	−2.3	−9.4
Kota Bharu	18.8	18.8	−0.1	−0.3
Tawau	6.5	7.8	1.3	+19.7
Sandakan	9.0	11.0	2.0	+22.7
Kota Kinabalu	13.1	10.4	−2.7	−20.4
Kimanis	16.1	11.3	−4.8	−29.6
Keningau	12.6	11.3	−1.3	−10.2
Labuan	16.6	13.0	−3.6	−21.9
Limbang	9.2	9.7	0.4	+4.7
ILP Miri	21.2	15.8	−5.3	−25.2
Miri	12.7	11.2	−1.5	−11.5
Samalaju	12.1	11.9	−0.2	−1.7
Bintulu	13.7	13.4	−0.4	−2.6
Mukah	7.4	7.3	−0.1	−1.7
Kapit	6.3	7.2	0.9	+14.2
Sibu	10.6	8.4	−2.2	−21.0
Sarikei	7.0	7.1	0.1	+2.0
Sri Aman	7.3	8.2	0.9	+12.6
Samarahan	7.2	10.0	2.9	+39.9
Kuching	8.8	10.8	2.0	+22.9
Johan Setia Klang (MCAQM)	32.0	26.2	−5.8	−18.2
IPD Serian (MCAQM)	6.9	7.1	0.2	+3.5
Politeknik Kota Kinabalu (MCAQM)	19.1	15.0	−4.1	−21.3

$PM_{2.5}$ concentrations mostly occurred after the MCO I. The movements and activities of residents living in the red zone area may have been restricted; however, pollutant emissions, especially from mobile sources had indirectly reduced in such areas.

In Malaysia, Jerantut (S40) is considered as the background station (rural). Unfortunately, it did not show the lowest $PM_{2.5}$ concentrations as expected whereby the $PM_{2.5}$ concentrations before MCO was 12.5 μg/m^3 and during MCO was 12.9 μg/m^3 with an additional of

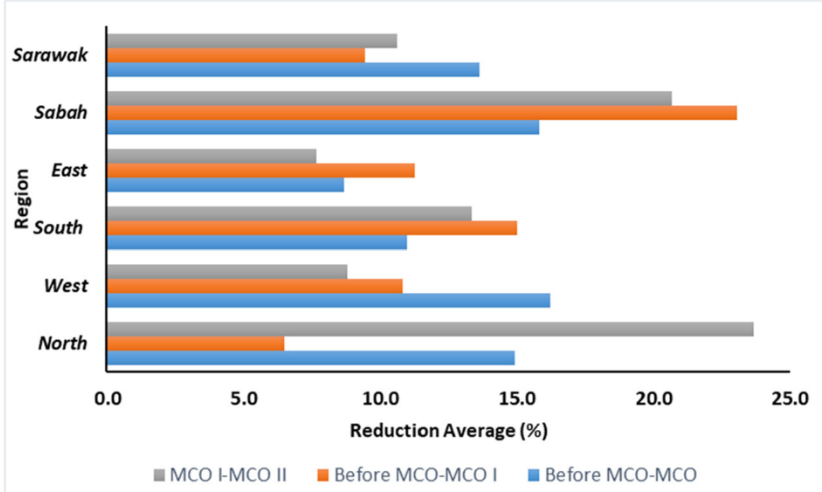

Fig. 1. Reduction average based on different regions.

2.7%. The variation of $PM_{2.5}$ concentrations was further increased with the increment of 10.7% when the researchers compared the $PM_{2.5}$ concentrations before MCO (12.5 μg/m^3) and during MCO I (13.9 μg/m^3). It showed a decreasing variation (14.5%) between MCO I and MCO II, with 13.9 μg/m^3 and 11.9 μg/m^3, respectively. The researchers observed that this station did not show the lowest $PM_{2.5}$ concentrations as a representative background station, thus a further study needs to be conducted by considering the other factors, including meteorological and the anthropogenic sources to justify the variation of $PM_{2.5}$ at this station as compared with other stations. Previously, Latif et al., (2014) clarified that there is an emergence of development around 10 km radius from the station. This could affect the condition of the station as a background. A background station must be located at a remote area which has minimal influence of anthropogenic sources.

4. Conclusion

In this study, the researchers concluded that the MCO has significant effects in reducing the $PM_{2.5}$ concentrations in Malaysia. It should be noted that other factors, such as weather conditions, traffic density, industrial activities, and biomass burning should be considered for further investigations. The MCO has been continued in Phase III, which started on 15 April 2020, and the $PM_{2.5}$ concentrations are expected to continue to stay low, as several areas have been placed under enhanced MCO.

CRediT authorship contribution statement

Samsuri Abdullah: Methodology, Writing - original draft, Writing - review & editing. **Amalina Abu Mansor:** Investigation, Formal analysis. **Nur Nazmi Liyana Mohd Napi:** Investigation, Formal analysis. **Wan Nurdiyana Wan Mansor:** Methodology. **Ali Najah Ahmed:** Methodology. **Marzuki Ismail:** Methodology. **Zamzam Tuah Ahmad Ramly:** Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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