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LOCKDOWN EFFECT ON CARBON MONOXIDE CONCENTRATION OVER MALAYSIA AND INDONESIA

Key words: carbon monoxide (CO), COVID-19, lockdown, pandemic, MERRA-2, Giovanni 4

Introduction

Coronavirus disease 2019, which is known as COVID-19, is a highly spreadable disease which was first discovered around December 2019 in Wuhan City, Hubei province, China. On 11 March 2020, the World Health Organization (WHO) had announced COVID-19 as a global pandemic as the novel coronavirus continues to spread worldwide extremely fast. Globally, up to 24 April 2021, there had been 145,216,414 confirmed cases and 3,079,390 deaths reported (World Health Organization [WHO], 2021). Malaysia, Indonesia

and other southeast Asian countries had enforced lockdown at different degrees to control the spread of the disease as did many other countries around the world too. Almost all mass transportation, economic activities and social activities were prohibited by this nationwide lockdown policies as many countries had been forced to keep their citizens safe at home. Owing to the movement limitation, there had been less vehicles on the roads, many cancelled flights and restricted industrial activities which led to decreasing levels of air pollutants in the environment. As a result of this lockdown effect, there has been a benefit on human health upon reduced air pollution.

Carbon monoxide (CO) is one of the air pollutants that needs to be monitored at

high resolution since these compounds will deteriorate human health if present at high concentrations (Manisalidis, Stavropoulou, Stavropoulos & Bezirtzoglou, 2020). Carbon monoxide is identified as chemically reactive trace gas that will threaten human health because it has 200 times greater affinity for hemoglobin than carbon dioxide (CO₂) (Perutz, 1990). Breathing high concentrations of CO leads to the reduced amount of oxygen transported in the blood stream to important human organs that can cause headaches, confusion, unconsciousness, brain damage or death (Fisher, Iscoe, Fedorko & Duffin, 2011). Carbon monoxide gas usually comes from four major sources: fossil fuel combustion, industrial combustion, biomass burning and oxidation of methane and other hydrocarbons (Azhari, Mohamed & Latif, 2016). Transportation combustion accounts about 50% of the total industrial source of carbon monoxide especially in the urban industrial areas (Azhari et al., 2016).

Globally, recent research has been focusing on the effect of the lockdown due to the COVID-19 pandemic on air quality especially on CO gas across nationwide. Collivignarelli et al. (2021) demonstrated a significant decrease of CO concentration mainly due to the severe limitation of people movements in the Metropolitan City of Milan following the partial and the subsequent total lockdown. Furthermore, Kerimray et al. (2020) in their study also proved that there was a significant decrease in CO concentrations by 49% during the COVID-19 lockdown period in Almaty, Kazakhstan compared to the days before the lockdown. The results could be due to the combination of seasonal weather changes and traffic elimination in Almaty, Kazakhstan. It may have also been considerably contributed by various non-traffic related

sources such as power plants and coal-fired combined heat. The effect of COVID-19 pandemic lockdown on the megacity Delhi, India air quality has also been investigated. The CO concentrations were monitored for different monitoring stations and the results proved that during lockdown it decreased and was indeed better compared to the time before lockdown. Moreover a research by Mahato, Pal and Ghosh (2020) found that CO concentration in the transportation and industrial area showed a significant decrease of 30.35% during lockdown phase. It is also reported that the decreasing trend of CO concentration was found on the second to fourth day of lockdown (Mahato et al., 2020).

There are several studies conducted on the lockdown impact due to the COVID-19 pandemic on Southeast Asian region on CO concentration especially in Malaysia and Indonesia. Nadzir et al. (2020) showed the effect of total lockdown in Klang Valley, Malaysia on CO gas during COVID-19 pandemic. From the observation, 48.7% of CO gas has been depleted. The results from this research revealed that the air pollutants such as CO gas could be reduced if the Malaysian authorities control the traffic and industry emissions strictly. In Jakarta, Indonesia, it was Anugerah, Muttaqin and Purnama (2020) who first conducted a study that used ground-level measurement data to measure the effect of lockdown on outdoor air quality. During lockdown, the CO concentration showed the most significant reduction at the percentage of 39.9% (Anugerah et al., 2020). Recent studies in Malaysia and Indonesia have only focused on big cities of these two countries and do not cover the entire country. Therefore, the focus of this paper is to determine the CO distribution over Malaysia and its neighbouring territory,

Indonesia, for a period from January 2011 to December 2021 using online Geospatial Interactive Online Visualization and Analysis Infrastructure (Giovanni). NASA Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) provides the data for surface concentration of CO that has been used in this study. It is hoped that results from this study could assist the authorities in formulating the best management procedure and air quality control methods to control air pollution. This study is conducted to investigate a span of nine years of CO concentration over Malaysia and Indonesia.

Methodology

In this study, atmospheric dataset was obtained from the Giovanni 4 interface. Firstly, CO concentration analysis assimilated by Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) was chosen. MERRA-2 is a NASA atmospheric reanalysis that provides data beginning in 1980 and known as the first long-term global reanalysis to provide an ongoing near-real-time climate analysis. It is intended as an intermediate reanalysis, developing an integrated Earth system analysis (IESA) capability that couples with the assimilation systems for the atmosphere, ocean, land, and chemistry. MERRA-2 also includes aerosol data assimilation, thereby providing a multidecadal reanalysis in which aerosol and meteorological observations are jointly assimilated within a global data assimilation system (Gelaro et al., 2017).

All data collections from MERRA-2 are provided on the same horizontal grid where this grid has 576 points in the longitudinal direction and 361 points in the latitudinal

direction, corresponding to a resolution of $0.625^{\circ} \times 0.5^{\circ}$ (Gelaro et al., 2017). After the study area was selected, the time averaged map for the period of January 2011 to December 2021 was plotted. The month-long lockdown is then constructed by using the same geographical coordinates. The month-long lockdown compute averages for January 2021 until December 2022 where mostly government around the world began nationwide lockdown. Time series were then plotted by using monthly area averaged time series that can be downloaded in Microsoft Excel format.

Study area

Geographically, Malaysia and Indonesia are located in Southeast Asia region (94.0869E, 9.4189S, 119.3994E and 7.4561N). It is bordered by the South China Sea to the east and Indian Ocean to the west. Malaysia is situated in central Southeast Asia, bordering in the north, with Singapore to the south and Indonesian to the south and west. Malaysia consists of Peninsular Malaysia and the states of Sabah and Sarawak on the north coast of the island of Borneo across the



FIGURE 1. The geographically feature of study area

South China Sea. Topographically, Indonesia is divided into three major regions: Sumatera to the north, Kalimantan to the east and Java to the south (Fig. 1).

Result and discussion

A spatial CO concentration is observed over the studied region. Figure 2 is a time averaged map that was constructed to find the general view of CO distribution over the study region (Malaysia and Indonesia). From the period of January 2011 to December 2021, there are five main regions that recorded high reading of CO concentration: Kuala Lumpur, Riau, Jambi, Palembang and Jakarta.

From this 10 years' time series, the highest spike was observed in Jakarta region that located at the south of island of Sumatera. The contributing factor for these high values of CO concentration is consistent with Rana, Mahmood, Tariq and Qayyum (2015) who reported that the increasing CO emission is

due to deforestation and urbanization in the region. The study conducted by Lavorel, Flannigan, Lambin and Scholes (2007) found that fire is a dominant factor that contributes to the largest anthropogenic influences CO emission after agricultural activities and urbanization. This is a very critical element that gives huge impacts to social, economic, and environmental activities. In addition, Southeast Asia has many social, economic, and environmental impacts caused by forest and land fires. Fire is considered one of the largest anthropogenic influences on terrestrial ecosystems after agricultural activities and urban, and it is indeed a critical element (Lavorel et al., 2007).

To find the exact time (year and month) that recorded the highest spike of CO concentration, area averaged time series for study period was constructed as shown in Figure 3. In this section, the 10-years of CO concentration retrieved over Jakarta, Kuala Lumpur, Riau, Palembang, and Jambi will be discussed.



FIGURE 2. Time averaged map of CO surface concentration in ppbv (ENSEMBLE) monthly $0.5^{\circ} \times 0.625^{\circ}$ over the period of January 2011 to December 2021

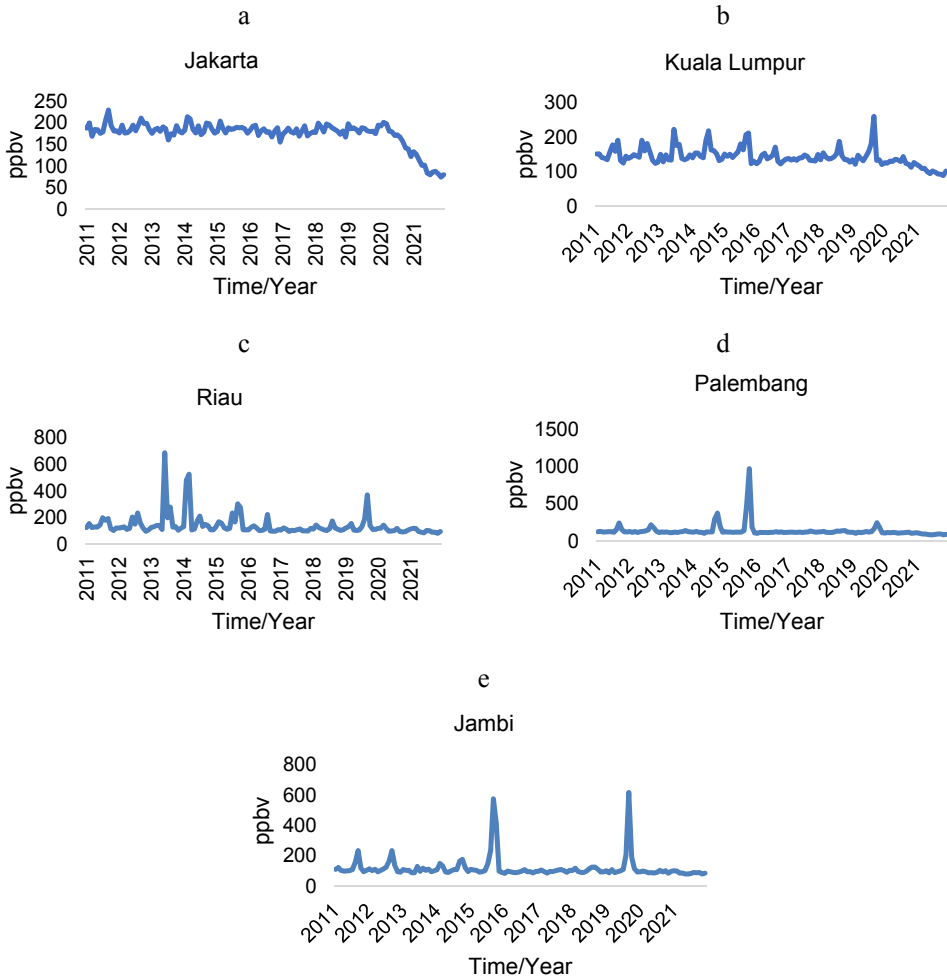


FIGURE 3. Area-averaged of CO surface concentration in ppbv (ESEMBLE) time series over (a) Jakarta, (b) Kuala Lumpur, (c) Riau, (d) Palembang, (e) Jambi from January 2011 to December 2021

Jambi and Riau region were reported as the worst region affected by the CO value as high as 638.4248 ppbv in June 2013, and Jambi was found with a CO concentration of 640.0425 ppbv in September 2019. The area averaged of CO concentration time series over Jakarta during the study period is presented in Figure 3a. For Jakarta, the satellite data show the highest spike in September 2011 and July 2018 with the

values of 372.353 ppbv and 372.0188 ppbv respectively. The highest spike recorded by Kuala Lumpur is 333.2772 ppbv in September 2019 as shown in Figure 3b.

Figure 3c presents the CO values over Riau region with four peaks exceeding 300 ppbv with increasing values of CO that were observed in June 2013, February to March 2014 and September 2019. The CO concentration over Palembang region

as shown in Figure 3d, observed the highest CO concentration with the value of 618.4915 ppbv in October 2015, followed by September 2019 with 314.7835 ppbv. As shown in Figure 3e, Jambi region was the most affected region during Indonesia's forest fire in September 2019; it exhibited the highest spike with the value of 640.0425 ppbv in September 2019 and 573.931 ppbv in September 2015.

The above findings show that the period with the high reading of CO concentration for the last 10 years is in September 2019. Studies conducted by Kamarudin, Muhammad, Sa'ad and Mustapha (2019) and Rajab, Tan, Lim and Mat Jafri (2019) discovered that the increasing CO concentration was mainly attributed to forest burning activities over Indonesia, automobiles, industrial activities, electricity generation, biomass and crop residue burnings that have caused adverse health and economic impacts not only to Malaysia and Indonesia, but also to Brunei Darussalam, Singapore and, to a lesser degree, the Philippines and Thailand. This is in line with an article reported by BBC Asia News (BBC, 2019) that stated the forest fire in

Indonesia had burnt 328,724 ha of land from January to August 2019. It also reported that large agricultural waste burning emission usually occurs from July to October during continuous dry season in Indonesia.

In order to trigger the exact location that had been most impacted by Indonesia forest fire in September 2019, a monthly area averaged was constructed as shown in Figure 4. It is observed that a high value of CO concentration exists over Jambi region which is associated with CO transport due to the occurrence of forest fire in central Sumatera's Jambi province. This is a combined effect causing the thick chocky haze that blanketed a large part of the region in September 2019 as reported by Kiki (2019). Freedman (2019) asserts that the wildfires turned the skies over Indonesia's Jambi province a dark blood red. This extreme biomass burning in Jambi, Indonesia in September 2019 had caused Malaysia and Indonesia to experience a high CO concentration which was significantly influenced by CO transport from the Jambi province.

As COVID-19 pandemic hit the whole world at the end of 2019, these five cities exhibited low level of CO concentration

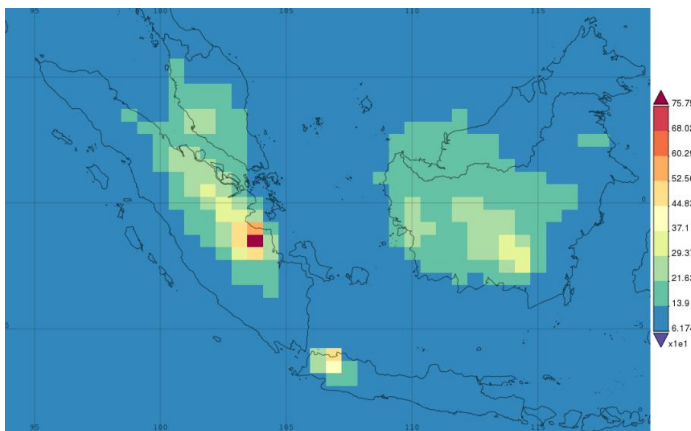


FIGURE 4. Monthly area averaged for September 2019

throughout 2020 and 2021. This is due to COVID-19 pandemic and most governments around the world began or extended nationwide lockdown to stem the coronavirus pandemic (Harris, 2020). It can be seen in Figure 5 where the comparison between CO concentration before COVID-19 pandemic (2019) and during COVID-19 pandemic (2020 and 2021) shows a decreasing trend from September 2019 to December 2021. In addition, from Figure 5, it seems likely that no high peak was recorded during dry season (July to October) in 2020 and 2021. As shown in Figure 5a, the CO concentration for Kuala Lumpur region was decreased after September 2019 and readings continued to decline in the year 2020 and 2021.

A responsible factor for this declining trends is the Movement Control Order (MCO) implemented by the federal government of Malaysia on 18 March 2020 as a preventive measure in response to COVID-19 pandemic. This restriction covers prohibitions on mass movement and gatherings countrywide, interstate, and inter-district travel bans among Malaysians, as well as entry and movement restrictions for the tourists. Government also issued “stay-at-home” order instructing residents to restrict their daily movements. Malaysia moved into the Conditional Movement Control Orders (CMCO) from 4 May 2020 and it ran until 9 June 2020. The CO concentration in August 2020 slightly increased higher as Malaysia moved into the Recovery Movement Control Order (RMCO) starting from 10 June until 31 December 2020 and then extended until 31 March 2021. As Malaysia was battling for the second wave of coronavirus spread, the total lockdown was implemented again from 1 June 2021 until 28 June 2021, which

then moved to the National Recovery Plan (NRP) from 15 June 2021 until 31 December 2021.

When MCO, CMCO, RMCO and NRP were implemented, the satellite data shows the decreasing trend of CO concentration compared to before the implementation of the series of lockdowns. This is in line with an article by Taufik (2020) who analysed the contrast pattern of lower CO concentration and fewer fire hotspots across the study region. He estimated that 206,751 ha of land area were affected by fire from January to September 2020 (during pandemic COVID-19). This author also found that the dry season in the year 2020 which was wetter than usual was responsible for the lower CO emission in the widespread smoke from the fire set by agricultural burnings in Sumatera and Kalimantan.

Meanwhile, starting from October 2019, the Indonesia regions of the study area consisting of Jakarta, Riau, Palembang, and Jambi have shown a relatively lower CO concentration. This is the combined effect of wetter dry season and the impact of lockdown implemented by Indonesia which can be seen in Figure 5(b–e). Partial lockdown was implemented in Indonesia and was imposed as large-scale social restrictions (LSSR) as a measure of social distancing and controlling the spread of virus (Andriani, 2020). As to counter the declaration of COVID-19 as a pandemic by the WHO, the regional government initiated to limit the movement of people such as closing down schools and workplaces, shutting down public transportation, imposing a limitation on physical worship, and social-cultural activities, and implementing “stay at home” policy as reported by Anugerah et al. (2021). Furthermore on 7 January 2021, Indonesian regions introduced the Community Activities

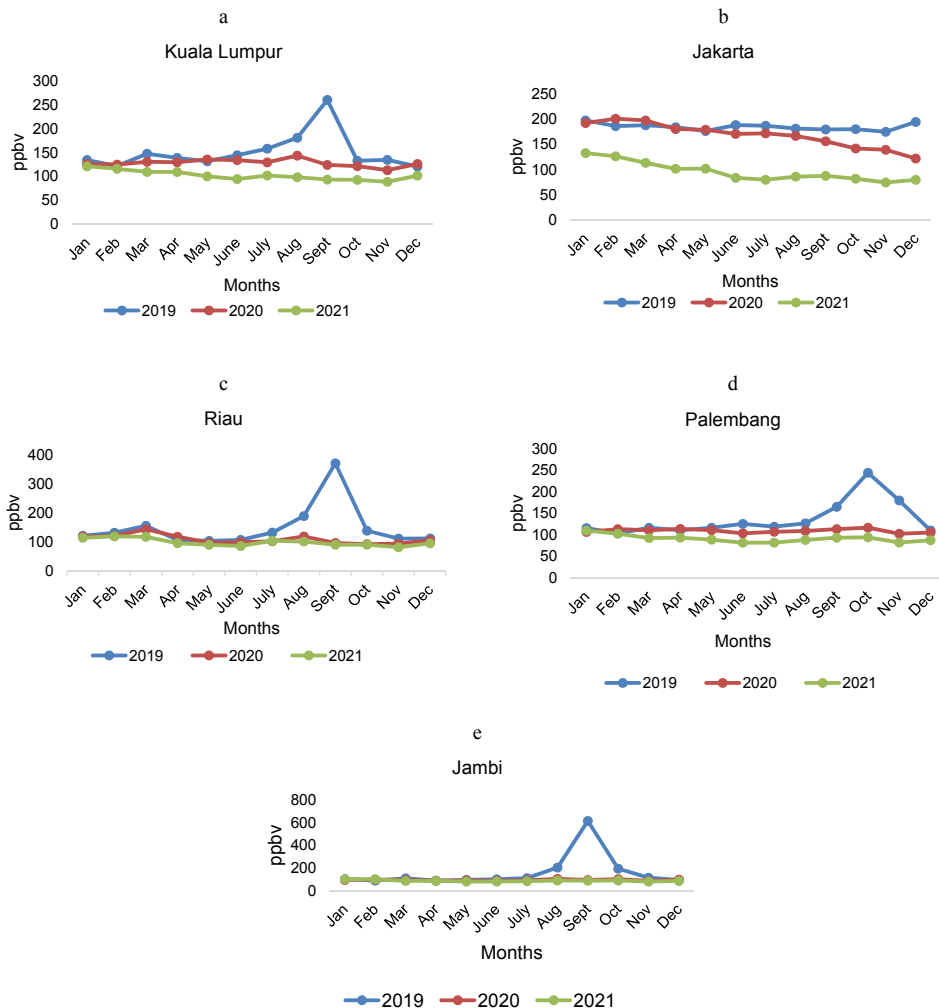


FIGURE 5. Monthly readings of CO surface concentration in ppbv (ESEMBLE) time series over (a) Kuala Lumpur, (b) Jakarta, (c) Riau, (d) Palembang, (e) Jambi before COVID-19 pandemic (2019) and during COVID-19 pandemic (2020 and 2021)

Restrictions Enforcement in some red zone areas, including the capital Jakarta and East Java province, in response to the second wave of coronavirus spread.

As both Malaysia and Indonesia are battling a second wave of coronavirus infections. Jong (2021) observed a decreasing trend for CO concentration in Indonesia

in the year 2021. The author also reported that the official data showed fire burnings of 35,271 ha of land from January to May 2021, a 9% decrease from the same period in 2020. This indicates that a reduction in CO concentration after the period of enforced lockdown is mainly due the absence of large-scale forest fires in this study regions

during COVID-19 pandemic (2020 and 2021). During the COVID-19 pandemic, the power requirements of the manufacturing sector, transportation, automobiles, industrial activities, and electricity generation also had declined, which in turn influenced the usual CO emission.

Conclusions

This paper has reviewed the effect of lockdown to CO concentration over Malaysia and Indonesia during pandemic COVID-19. MERRA-2 dataset provided by Giovanni interface was used to analyse CO surface concentration over Malaysia and Indonesia for a period of 10 years from January 2011 to December 2021. Five affected areas which are, Kuala Lumpur, Jambi, Riau, Palembang, and Jakarta were found to have higher CO value during the study period. The month of September 2019 is found to have the highest trend of CO concentration over Jambi region. The increase of CO concentrations is mostly due to the common occurrence of forest fire during the drought season which has been identified as the main source of CO emissions. As COVID-19 pandemic hit the whole world at the end of 2019, all the studied regions showed a decreasing trend after September 2019 and no high peak was observed throughout the year 2020 and 2021. This is the combined effect of wetter dry season, absence of large-scale forest fire and the impact of lockdown implemented by the both governments of Malaysia and Indonesia.

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Summary

Lockdown effect on carbon monoxide concentration over Malaysia and Indonesia. An increase in Indonesian forest fires has infuriated Malaysia and Indonesia, where residents are inhaling smoke from peat and trees burned hundreds of miles away. The global COVID-19 lockdowns caused carbon monoxide (CO) emissions decreased seen over Malaysia and Indonesia regions. The main objective of this study is to investigate the CO distribution over Malaysia and Indonesia, within the period of January 2011 to December 2021. The impact of lockdown due to COVID-19 pandemic in 2020 and 2021 to CO concentration over Malaysia and Indonesia also was reviewed. This study utilizes MERRA-2 dataset provided

by Giovanni interface. Five areas were found to be affected the most during the study period which is Kuala Lumpur, Jambi, Riau, Palembang, and Jakarta. Carbon monoxide concentration over the studied region exhibits a strong seasonality showing maximum value in dry season (July to October). September 2019 is found to have the highest trend of CO concentration affected Jambi region. As COVID-19 pandemic hit the whole world by end of year 2019, all the studied regions shown the decreasing trend after September 2019 and no high peak was observed during dry season (July to October) in 2020 and 2021. This is the combined effect of wetter dry season and an impact of lockdown implemented by government of Malaysia and Indonesia.