Some Comments on Air Pollution Levels over Iraq during Covid-19 pandemic period Employing Remotely Sensed Data

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Abstract

Tropospheric Carbon monoxide (CO), Total ozone (O₃), Nitrogen dioxide (NO₂) data derived from Atmospheric Infrared Sounder (AIRS) and Ozone Monitoring Instrument (OMI) sensor on board NASAs Aqua and Aura satellite platforms respectively, These instruments provide consistent spatial and temporal coverage and permit the study of anthropogenic and natural emissions on local-to-global scales. In present paper the employed data product have been analyzed and mapped over Iraq, for 3-year period (2017–2019). Analysis of the study period showed that the overall mean CO, O₃, and NO₂ over Iraq were (110 ± 6) ppb, (306 ± 12) DU, and (3.80 ± 2) × 10¹⁴ /cm² respectively. The CO has significant variation with a maximum in spring and winter season, and minimum in summer and fall season. O₃ records presented a unique peak which was extended from late-winter (February) to late-spring (May). The NO₂ have no obvious seasonal variation. With the highest values occurred during autumn and winter and lowest values happened during spring and summer. Which are mainly concentrated in the most populated cities in country especially Baghdad city. This paper investigated an assessment status pollution levels includes (CO, O₃, NO₂) for the period from (January - May) before and during Covid-19 pandemic period particularly in curfew periods, which measures taken for the pandemics impacts on environmental air quality.

Keywords: Air pollution, Remote Sensing, Covid-19, pandemics, climate change.

Uzaktan Algılanan Verilerin Kullanılmasıyla Kovid-19 Pandemi Döneminde Irak Üzerindeki Hava Kirliliği Düzeylerine İlişkin Bazı Yorumlar

Özet

Troposferik karbon monoksit (CO), toplam ozon (O₃) ve azot dioksit (NO₂) verileri NASA'nın Aqua ve Aura uydu platformlarında bulunan Atmosferik Kızılötesi Siren (AIRS) ve Ozon İzleme Aleti (OMI) sensöründen elde edilmiştir. Bu aletler tutarlı uzaysal sağılar ve geçici kapsam ve yerelden küresel ölçeklerde antropojenik ve doğal emisyonların çalışmasına izin verir. Bu yazıda, kullanılan veri ürünü Irak üzerinden 3 yıllık (2017-2019) dönem için analiz edilmiş ve haritalanmıştır. Çalışma süresinin analizi, Irak'a göre genel ortalama CO, O₃ ve NO₂'nin sırasıyla (110 ± 6) ppb, (306 ± 12) DU ve (3.80 ± 2) × 10¹⁴ /cm² olduğunu gösterdi. CO, ilkbahar ve kış mevsiminde maksimum ve yaz ve sonbahar mevsiminde minimum olmak üzere önemli bir varyasyona sahiptir. O₃ kayıtları, kış sonundan (Şubat) ilkbahar sonlarına (Mayıs) kadar uzanan benzersiz bir zirve sundu. NO₂'nin belirgin bir mevsimsel değişimi yoktur. En yüksek değerler sonbahar ve kış aylarında, en düşük değerler ise ilkbahar ve yaz aylarında gerçekleşmiştir. Ağırlıklı olarak ülkenin en kalabalık şehirlerinde, özellikle de Bağdat şehrinde yoğunlaşmıştır. Bu makale, özellikle sokağa çıkma yasakları dönemlerinde, Covid-19 pandemisinde önceki (Ocak - Mayıs) dönem için (CO, O₃, NO₂) içeren kirlilik düzeylerinin değerlendirilmesini ve pandemilerin çevresel hava kalitesi üzerindeki etkilerini araştırmaktadır.

Anahtar Kelimeler: Hava kirliliği, Uzaktan Algılama, Covid-19, pandemiler, iklim değişikliği.

1. Introduction

Air quality is an important factor. Increased levels of air pollutants will affect human health. According to data supplied by the World Health Organization, air pollution and poor air quality result in 5.5 million deaths annually. The main

sources of air pollution are combustion from vehicles, power generation plants, landfill sites, wastewater treatment plants and unsustainable farming. these compounds(CO,O₃,NO₂) if present at high concentrations in air will deteriorate human health(Nadzir et al., 2020). Late December 2019, A novel infectious disease of coronavirus family was identified, in Wuhan, Hubei Province, China, which named as COVID-19.

In February 2020, outbreaks begin in Iran, Italy and other countries around the globe. The infection was declared by the World Health Organization (WHO) as a global pandemic in 11 March 2020 (Chen et al., 2020).

Up to Jun 18, 2020, the cumulative number of confirmed COVID-19 cases has exceeded (8,348,249) and 448,937 COVID-19 death cases have been reported globally with the majority of infections and deaths reported from western Europe and North America. Cumulative number of confirmed COVID-19 cases has exceeded in Iraq (36702) and death cases 1330. Lately, satellite measurements of air pollutants during the COVID-19 pandemic from the European Space Agency have shown that during late January and early February 2020, air pollution decreased markedly. Therefore, This paper investigated an assessment status pollution levels includes (CO , O_3 , NO_2) for the period from (January - May) before and during Covid-19 pandemic period particularly in curfew periods, which measures taken for the pandemics impacts on environmental quality (Xu et al., 2020). Carbon monoxide (CO) is one of the greenhouse gases, and it of the primary air pollutants cause a significant deterioration in air quality. The CO gas can pose threats to human health. CO forms during the biomass burning and combustion of fossil fuels and from the oxidation of CH_4 by OH radicals (Al-Salihi, Rajab, & Salih, 2019). Ozone (O_3) is a highly reactive gas composed of three oxygen atoms. It is both a natural and a man-made product that occurs in the Earth's upper atmosphere ozone molecule (the stratosphere) and lower atmosphere (the troposphere). Tropospheric ozone has a short lifetime of a few weeks. It contribute significantly to global warming and climate change phenomenon but on a timescale much smaller than CO_2 (Komala & Ambarsari, 2018). O_3 concentrations are high. It negatively affects human health and agriculture Environment. Tropospheric or ground-level ozone – what we breathe – is formed primarily from photochemical reactions between two major classes of air pollutants, volatile organic compounds (VOC) and nitrogen oxides (NO_x). These reactions have traditionally been viewed as depending upon the presence of heat and sunlight, resulting in higher ambient ozone concentrations in summer months. Although some stratospheric ozone is transported into the troposphere, and some VOC and NO_x occur naturally, the majority of ground-level ozone is the result of reactions of man-made VOC and NO_x . Significant sources of VOC are chemical plants, gasoline pumps, oil-based paints, auto body shops, and print shops. Nitrogen oxides result primarily from high temperature combustion. Significant sources are power plants, industrial furnaces and boilers, and motor vehicles (Daly & Zannetti, 2007). Nitrogen dioxide (NO_2) emission mostly originates from the burning of oil, coal, natural gas and other fuels and the exhaust of automobiles. NO_2 is an ambient trace-gas result of both natural and anthropogenic processes. Long-term exposure to NO_2 may cause a wide spectrum of severe health problems such as hypertension, diabetes, heart and cardiovascular diseases and even death (Shin et al., 2020). Some paper-based procedures for the spatial analysis number of death cases according to (COVID-19) found the highest deaths occurred were in five regions located in north Italy and central Spain. In addition to, the same five regions show the highest NO_2 concentrations combined with downwards airflow which prevents an efficient dispersion of air pollution. These results indicate that the long-term exposure to this pollutant may be one of the most important contributors to

fatality caused by the COVID-19 virus in these regions and maybe across the whole world (Ogen, 2020).

2. Study Area

Iraq is an Arab country consisting of eighteen provinces, which is one of the West Asian countries bordering the Arabian Gulf. The area of Iraq is 434,924 km^2 , and it is located at latitude of $38^\circ 45' - 48^\circ 45'$ East of the Greenwich line, and $29^\circ 5' - 37^\circ 15'$ North of the equator. It is bordered to the south by Kuwait and Saudi Arabia, to the north by Turkey, to the west by Syria and Jordan, and to the east by Iran as shown in Figure 1. The major biggest cities in Iraq, including Mosul, Baghdad and Basra are highly-populated cities. The country can be divided into approximately four geographical regions: The Desert areas in the West and Southwest, the mountains in the North and Northeast, The Alluvial plan through which the Tigris and Euphrates river flow, and rolling upland between the upper Euphrates and Tigris river (Al-Bayati & Al-Salihi, 2019). The climate in Iraq is affected by monsoons; Northwestern winds blow in the summer, steady in the north, and strong southeastern winds in the winter in the East. Average temperatures in Iraq range from (50°C) in summer, and in winter range (0°C). As for autumn and spring, they appear in short transitional periods of time. Rainfall is seasonal, where rainy season start from November to April over almost Iraq regions, mean annual rainfall about 216 mm, it ranges from 1200 mm in the northeast to less than 100 mm over 60 percent of the southern parts of Iraq (Salih, Al-Salihi, & Rajab, 2018).

2.2.

Figure 1: The geographical location of study area (Iraq).

3. Data acquisition

The acquired CO , Ozone and NO_2 data set were chosen for the period (2017-2020) using the ascending AIRS3STM_006_O3_VMR_A (on spatial resolution of $10^\circ \times 10^\circ$), and OMI instrument (on spatial resolution of $0.25^\circ \times 0.25^\circ$) respectively, for the study area Iraq. CO , O_3 and NO_2 monthly data set were used for the three main Iraq cities (Mosul, Baghdad and Basra). AIRS the Advanced Infrared Sensor flying on Aqua satellite mission is a unique hyper spectral thermal IR radiometer, designed by NOAA and NCEP's research programs. The infrared sounder AIRS were launched in May 2002 by satellite (NOAA AQUA), after the test period, the data were received in October 2002. AIRS is

aboard on the Aqua satellite with the crossing time of the equator 01:30 and 01:30 local time (Thomas, Watson, Carn, Prata, & Realmuto, 2011). The AIRS infrared spectrometer acquires 2378 spectral channels at high spectral resolution ($\lambda/\lambda = 1200$) and low noise, covering the main spectral features of carbon trace gases CO_2 , CH_4 , O_3 and CO . Practically AIRS supply global distributions of CO in real time using radiances around 4.58 and $4.50 \mu\text{m}$ ($2183\text{--}2220 \text{ cm}^{-1}$) of region spectra in the 1-0 vibration-rotation CO fundamental (McMillan, Miller, & Nguyen, 2014). OMI instrument is a UV-VIS hyper-spectral, nadir-viewing satellite spectrometer on the NASA EOS Aura satellite which launched in July 2004. Aura has an equator crossing time of 13:30 LST and an orbital period of 99 min so that OMI views the entire sunlit portion of the Earth in 14.5 orbits. On each orbit, OMI makes simultaneous measurements in a swath of width 2600 km, divided into 60 fields of view (FOVs), or pixels. One swath is measured every two seconds, for approximately 1650 swaths from southern to northern terminator on the sunlit side of the earth (Bucsela et al., 2013).

4. RESULTS AND DISCUSSION

4.1. Regional CO , O_3 and NO_2 pollution monthly variation

Regional maps of tropospheric Carbon monoxide (CO), Total column ozone (O_3), and Nitrogen dioxide (NO_2) which highlight hot spot pollution data were generated employing Kriging interpolation technique for the monthly mean database observed for the period (January 2017 to December 2019). The data were obtained from the AIRX3STM, $1^\circ \times 1^\circ$ spatial resolution ascending data for CO , O_3 , and from OMI NO_2 v003, $0.25^\circ \times 0.25^\circ$ standard gridded for NO_2 as illustrated in Figure 2 (a, b and c). The CO maximum values occurred during the winter (December, January and February) and spring (March, April and May) months, mainly during February and March reached up to (135 ppb), and northern with northern east area have the highest CO values throughout

On 20 March 2020, Iraq governments applied quarantine to control the spread of COVID-19, Figures 3, a, b, and c show the tropospheric Pollutant CO , O_3 , and NO_2 emissions over Iraq between the periods January to May 2019 and 2020. Based on the data from the three cities; Mosul, Baghdad, and Basra. The percentage change of CO , O_3 and NO_2 emissions of the different months was tabulated in Table 1. Before the pandemic in the period between January and February 2020, it is clear from the Figures that Pollutant CO , O_3 , and NO_2 emission levels in Iraq are high compared to the same period in 2019. One possible explanation could be the frequent periodic rains in 2019 compared to the same period in 2020 that significantly wash out air pollutants as illustrated in Figure 2 a and c, The concentrations of CO and NO_2 in March to May of 2020 was found consistently lower than in 2019 in major Iraq cities (table 1). After the COVID-19 pandemic period, A noticeable declines of anthropogenic pollutants concentrations were observed in almost world's cities particularly in industrial countries (Shrestha et al., 2020). The Maximum decline in CO and NO_2 levels was observed in Mosul followed by Baghdad and Basra as shown in table 1.

the year due to local emissions, with successive plumes contributed to CO concentrations are from Syria and Turkey drove by the prevailing north-northwesterly wind (Salih et al., 2018), whereas, CO emissions gradually decreases during the summer and autumn months, The minimum mean values reduced to (87 ppb) observed at the west and northwest regions in July, August and September. This reduction in CO is mostly connected to the negative correlation between CO and surface temperature as well as the direct influence of the southeasterly wind, which has large scale dynamics vertical mixing reducing the CO concentrations. The O_3 values show season dependent with values generally maximum for spring and minimum in winter. The O_3 maximum values were about (359 DU) observed from February to May over the northern and north western regions (above latitudes 34°N), and the minimum values in winter season between December and January at the south regions (262 DU) of the country as shown in Figure 2.b. The distribution of O_3 throughout the months of the year shows Latitudinal gradients from north to south regions because there were differences on weather and topography that lead to a great effect on tropospheric ozone distributions over Iraq. The average OMI NO_2 map (Figure. 2c) has no seasonal variation. With the maximum values observed in autumn and winter and minimum values in spring and summer. The highest values mainly observed over the most populated cities in the country especially Baghdad city ($8 \times 10^{15} \text{ cm}^{-2}$) during the winter season in December – February, also the highest NO_2 values observed in the south part of Iraq over the Arabian Gulf, where local NO_2 emissions occur as a result of flaring gas emissions, oil refinery, and shipping in the region. The lowest values ($0.2 \times 10^{15} \text{ cm}^{-2}$) observed in the whole Iraq area except the major high populated cities, this due to the low NO_2 emissions which coincide with small urban agglomerations, addition to year-round high temperatures, leading to shorter NO_2 lifetimes.

3.2 Pollution during pandemic period

The significant reductions in CO and NO_2 concentrations during the pandemic period (March - May, 2020) compared to the same period in 2019 in Mosul and Baghdad cities is more noticeable, could be due to the elimination of industrial, traffic activity and meteorological conditions change were the approval of air pollution reductions during the pandemic period compared to the preceding period in 2019. However, the reduction in CO and NO_2 emissions is less apparent at Basra city ($\leq 2\%$), as such emissions could have continued despite pandemic lockdown, which possibly attributed to the primary emission sources (oil refinery and gas-burning) dominate the pollution profile over Basra city. Unlike to CO and NO_2 , after the pandemic period (March - May, 2020) as shown in Figure 3c, the three cities had a clear enhancement in O_3 levels around 1-8% in different regions in the country. This result depicts that pandemic agglomeration did not influence on total ozone production. As known the O_3 is most related to photochemical reaction, the local availability of precursor gases and solar activity during the period of pandemic period modify production or the loss rates and hence impact the O_3 concentrations.

Figure 2: Spatial distribution of emissions of (a) CO, (b) O₃, (c) NO₂ over Iraq.

Table 1: Percent change of pollutant emissions in 2020 compared to 2019.

	CO			O ₃			NO ₂		
Month	Mosul	Baghdad	Basra	Mosul	Baghdad	Basra	Mosul	Baghdad	Basra
Jan	10%	12%	6%	14%	29%	31%	53%	34%	25%
Feb	3%	4%	7%	2%	8%	10%	36%	50%	28%
Mar	-9%	-8%	-4%	4%	4%	3%	-38%	-24%	-9%
Apr	-7%	-6%	-4%	8%	2%	2%	-46%	-33%	-3%

May -8% -7% -3% 5% 7% 4% -7% -21% -7%

Figure 3: Spatial distribution of pollutant emissions between (January - May) in 2019 (on top) and 2020 (on bottom) for (a) CO, (b) O₃, (c) NO₂, Iraq

4. Conclusions

The primary concludes remarks acquire from this study were summarized as follows:

1) The high CO values were observed during February and March, while the low values were in July, August, and September. For NO₂, the high values over the main populated cities in the country, whereas other Iraq areas showed low values throughout the year. The high O₃ value (359 DU) during (February – may), while the low values (262 DU) was in January .

2) Before the pandemic in the period between January and February 2020 Pollutant CO, O₃, and NO₂ emission levels in Iraq are high compared to the same period in 2019, this was expected to be due to seasonal changes in temperature and precipitation.

3) After the COVID-19 pandemic period (March-May, 2020), the concentrations reduced by ~ (6-9 %) for CO, and by~ (3-46%) for NO₂ due to the combination of traffic elimination and industrial operations, but O₃ increased by ~ (2-8 %) for main Iraq cities (Mosul, Baghdad and Basra). Local burning activities in the area are believed to be the main cause of the increased levels of O₃.

4) This study showed that the COVID-19 pandemic period in Iraq has remarkably controlled the air pollutants levels.

Acknowledgment

The authors wish to thank the NASA Goddard Earth Sciences Data Information and we thank systems engineering, and satellite integration teams for the access of the AIRS and OMI data used in this paper.

References

- Al-Bayati, R. M., & Al-Salihi, A. M. (2019). *Monitoring carbon dioxide from (AIRS) over Iraq during 2003-2016*. Paper presented at the AIP Conference Proceedings.
- Al-Salihi, A. M., Rajab, J. M., & Salih, Z. Q. (2019). *Satellite monitoring for Outgoing Longwave Radiation and Water Vapor during 2003-2016 in Iraq*. Paper presented at the Journal of Physics: Conference Series.
- Bucsela, E., Krotkov, N., Celarier, E., Lamsal, L., Swartz, W., Bhartia, P., . . . Pickering, K. (2013). A new stratospheric and tropospheric NO₂ retrieval algorithm for nadir-viewing satellite instruments: applications to OMI. *Atmospheric Measurement Techniques*, 6(10), 2607-2626.
- Chen, H., Guo, J., Wang, C., Luo, F., Yu, X., Zhang, W., . . . Gong, Q. (2020). Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. *The lancet*, 395(10226), 809-815.
- Daly, A., & Zannetti, P. (2007). An introduction to air pollution—definitions, classifications, and history. *Ambient air pollution*. P. Zannetti, D. Al-Ajmi and S. Al-Rashied, *The Arab School for Science and Technology and The EnviroComp Institute*, 1-14.
- Komala, N., & Ambarsari, N. (2018). *Seasonal Variability Of Ozone Vertical Profiles in Indonesia Based on AQUA-AIRS Data*. Paper presented at the IOP Conference Series: Earth and Environmental Science.
- McMillan, B. D., Miller, G. J., & Nguyen, J. (2014). Rare case of exogenous *Candida dubliniensis* endophthalmitis: a case report and brief review of the literature. *Journal of ophthalmic inflammation and infection*, 4(1), 1-4.
- Nadzir, M. S. M., Ooi, M. C. G., Alhasa, K. M., Bakar, M. A. A., Mohtar, A. A. A., Nor, M. F. F. M., . . . Ariff, N. M. (2020). The impact of movement control order (MCO) during pandemic COVID-19 on local air quality in an urban area of Klang valley, Malaysia. *Aerosol and Air Quality Research*, 20(6), 1237-1248.
- Ogen, Y. (2020). Assessing nitrogen dioxide (NO₂) levels as a contributing factor to coronavirus (COVID-19) fatality. *Science of the Total Environment*, 726, 138605.
- Salih, Z., Al-Salihi, A. M., & Rajab, J. M. (2018). Assessment of Troposphere Carbon Monoxide variability and trend in Iraq using Atmospheric Infrared Sounder during 2003-2016. *Journal of Environmental Science and Technology*, 11(1), 39-48.
- Shin, S., Bai, L., Oiamo, T. H., Burnett, R. T., Weichenthal, S., Jerrett, M., . . . Kopp, A. (2020). Association between road traffic noise and incidence of diabetes mellitus and hypertension in Toronto, Canada: a population-based cohort study. *Journal of the American Heart Association*, 9(6), e013021.
- Shrestha, A. M., Shrestha, U. B., Sharma, R., Bhattarai, S., Tran, H. N. T., & Rupakheti, M. (2020). Lockdown caused by COVID-19 pandemic reduces air pollution in cities worldwide.
- Thomas, H. E., Watson, I. M., Carn, S. A., Prata, A. J., & Realmuto, V. J. (2011). A comparison of AIRS, MODIS and OMI sulphur dioxide retrievals in volcanic clouds. *Geomatics, Natural Hazards and Risk*, 2(3), 217-232.
- Xu, K., Cui, K., Young, L.-H., Wang, Y.-F., Hsieh, Y.-K., Wan, S., & Zhang, J. (2020). Air quality index, indicator air pollutants and impact of COVID-19 event on the air quality near central China. *Aerosol and Air Quality Research*, 20(6), 1204-1221.