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Impact of COVID -19 pandemic lockdown on distribution of inorganic pollutants in selected cities of Nigeria

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Abstract

The COVID-19 global pandemic has necessitated some drastic measures to curb its spread. Several countries around the world instituted partial or total lockdown as part of the control measures for the pandemic. This presented a unique opportunity to study air pollution under reduced human activities. In this study, we investigated the impact of the lockdown on air pollution in three highly populated and industrious cities in Nigeria. Compared with historical mean values, NO_2 levels increased marginally by 0.3% and 12% in Lagos and Kaduna respectively. However, the city of Port Harcourt saw a decrease of 1.1% and 215.5% in NO_2 and SO_2 levels respectively. Elevated levels of O_3 were observed during the period of lockdown. Our result suggests that there are other sources of air pollution apart from transportation and industrial sources. Our findings showed that the COVID-19-induced lockdown was responsible for a decrease in NO_2 levels in two of the locations studied. These results presents an opportunity for country wide policies to mitigate the impact of air pollution on the health of citizens.

Keywords Air quality · COVID-19 · Pollution

Introduction

Pollution poses a significant threat to human health and the world at large. Diseases like cancer, respiratory diseases, negative pregnancy outcomes, infertility, cardiovascular diseases, stroke, and cognitive decline have been attributed to air pollution (Sweileh et al. 2018). Inorganic air pollutants include ozone (O_3), airborne lead (Pb), carbon monoxide (CO), sulphur oxides (SOx), and nitrogen oxides (NOx) (Sweileh et al. 2018). Ozone (O_3) is present in the troposphere, as well as in the stratosphere. Tropospheric ozone is formed when nitrogen oxides (NOx) from fossil fuel burning sources like power plants and automobiles undergo chemical reactions with volatile organic compounds (VOCs) from gasoline and solvents in the presence of sunlight. The free oxygen atoms combine with oxygen molecules. Tropospheric ozone is both a greenhouse gas and air pollutant. It causes respiratory diseases such as dyspnea, upper airway irritation, coughing and chest tightness (Chen et al. 2007b). Stratospheric ozone, which is about 90% of the ozone in the atmosphere, acts as a protective shield because it absorbs the ultraviolet radiation from the sun (Langematz 2019).

Exposure to nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) causes mild respiratory diseases like dyspnea, homptysis, cough, and sometimes death (Chen et al. 2007a). It was reported in Guardian (2016) that over one million people died from polluted air in China in 2012, over 600,000 in India, over 140,000 in Russia, and over 46,000 in Nigeria respectively. Nigeria has a population of over two hundred million and there is dearth of information about her air quality. According to Marais et al. (2014),

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sources of air pollution in Nigeria are inefficient vehicles, bad road networks, high emissions of non-methane volatile organic compounds (NMVOCs), gas flaring in the Niger Delta region, illegal oil refining, gas leakage, pipeline explosions, carcinogenic polycyclic aromatic hydrocarbon (PAH) concentrations, diesel-powered back-up generators/plants, kerosene, and fuelwood. Aliyu et al. (2019) established that inferences of combined vehicular traffic contributed to observed pollution measurements in Kaduna, a city in Northern Nigeria. To better understand the source and role and limit the impact of pollution, there is the need to account for anthropogenic air pollution.

Corona virus disease (COVID-19) outbreak provided a means to investigate the impact of human activities on human population in different parts of the world at the same time. It is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first confirmed case of COVID-19 in Nigeria was on 27th February 2020. By 8th June 2020, 12801 cases have been confirmed with 361 deaths. Thirty-six states including the Federal Capital Territory (FCT) have reported at least one confirmed case (NCDC 2009). The Nigerian Government in response to COVID-19 outbreak put a lot of interventions in place. This includes the following: international travel bans, domestic air travel bans, closure of schools, universities, and religious places, ban on social and cultural activities, and general restriction of movements. This culminated in a lockdown (stay at home) order imposed by the Federal Government on States with very high infection rates while State Governments locked down their states to control the infection rates in their states at different times as the epidemic trajectory increases. On April 11, 2020, interstate travel was banned. The lockdown associated with COVID-19 provided a global opportunity to study the anthropogenic contributions to air pollution in locations around the world.

Collivignarelli et al. (2020) found that the effect of the partial and total lockdown by the Italian government in the Metropolitan City of Milan due to COVID-19 caused a reduction in the air pollutants caused by vehicular traffic. The air quality index (AQI) according to Sharma et al. (2020b) reduced in northern, southern, eastern, central, and Western India during the COVID-19 lockdown period when compared with pre-COVID-19 years. Reduction in air pollution due to COVID-19 lockdown has also been established in Kazakhstan (Kerimray et al. 2020), Brazil (Krecl et al. 2020), India (Karuppasamy et al. 2020), the USA (Shakoor et al. 2020), Ecuador (Zambrano-Monserrate and Ruano 2020), and Morocco (Otmani et al. 2020). The lockdown has been associated with better water quality in Vembanad Lake, India (Yunus et al. 2020), Venice (Braga et al. 2020) and clean beaches around the world (Zambrano-Monserrate et al. 2020). Wang et al. (2020) showed that reduction in anthropogenic activities did not translate to cleaner air for several locations in China. Zambrano-Monserrate et al. (2020) highlighted the negative effect of COVID-19 on the environment to include increased waste generation and reduction in waste recycling.

The continent of Africa, especially sub-Saharan Africa, has been largely left out of this consideration. The continent consist of developing countries with increasing levels of population and industrialization. The rural areas, due to lack of industrialization, engage in activities such as bush burning, open defecation, deforestation, and firewood cooking, which contributes to regional pollution. The aim of this paper is to study the effect of the COVID-19 lockdown measure on the air quality in three big cities of Nigeria, namely Lagos, Port Harcourt, and Kaduna.

Methodology

Ozone monitoring instrument (OMI) data

Ozone monitoring instrument (OMI) is a nadir-viewing imaging spectrometer aboard NASA's Aura Earth observing system (EOS) satellite, which was launched in July 15, 2004. Aura flies in a sun-synchronous polar orbit at a height of 705 km. The OMI sensor was designed to operate by sensing UV-Vis radiation at a wavelength of 310.8–314.4nm. It has an overpass across the equator between 13:40 and 13:45 local time (LT) with a very high spatial resolution (13 km × 24 km, and 13 km × 12 km) depending on the position within the swath, and covers the globe daily. Its high spatial coverage and resolution increase the sensor's probability of encountering cloud-free observations (Krijger et al. 2007). OMI measures criteria air pollutants such as O_3, SO_2, NO_2, and aerosol that are capable of harming human health and damaging agricultural productivity (www.epa.gov/criteria-air-pollutants). This study is based on 0.25° Lat/Lon daily O_3, SO_2, and NO_2 total column profile retrieved from level 3 (L3) OMI. The SO_2 (OMSO2e) and O_3 (OMTO3e) concentrations during 2004–2020, and NO_2 (OMNO2d) observations during 2005–2020 were analyzed for the selected regions.

Study area

The three locations selected in this study is based on the anthropogenic activities and emission inventories of the locations. Two cities, Lagos (6.22° N–6.42° N, 2.42 ° E–3.22° E) and Port Harcourt (4.78° N, 7.01 ° E), are in the southern Nigeria and Kaduna (9.02° N–11.32° N, 6.15° E–8.38° E) is in central part of northern Nigeria. Lagos is one of the most populous and fast growing cities in the West

Africa (zu Selhausen 2017). It is bounded in the Guinea coast of the Atlantic ocean in the south and Republic of Benin in the west and span to Ogun state in the east. It falls partly under rainforest and swampy mangrove region with mean annual rainfall of about 2000 mm (Oyewole et al. 2014). High pollution in Lagos city is caused by the combination of many strongly emitting vehicles and frequent traffic jams (Baumbach et al. 1995). According to Baumbach et al. (1995), SO_2 values within Lagos state varies between 0 and 100 ppb while carbon monoxide have values in the range 0–10 ppm. Port Harcourt (Garden city) is in humid region with an area of 360 km^2 and mean annual rainfall of 2400 mm (Salako 2008). The city is famous because of many petroleum industries. These industries emit pollutants through gas flaring which are capable of contaminating the environment. Carbon monoxide and SO_2 values within Port Harcourt have been found to exceed standard limits of safety (Augustine 2012). Kaduna is one of the largest cities in northern Nigeria, located at an altitude of 645 m. It falls under semi-arid region with an annual mean rainfall of about 1200 mm (Bununu et al. 2015). The major source of pollution in this region is from industrial activities (Abdulkareem et al. 2006). Nimyel and Namadi (2019) reported air pollutants values within Kaduna to include carbon monoxide (2.78–33.48 ppm), NO_2 (0.006–0.052 ppm), and SO_2 (0.003–0.037 ppm).

Results and discussion

The time series of the three air pollutants considered in this work from 2005 until 2020 are presented in Fig. 1. All the time series were found to have seasonal variation. This is largely due to the activities and climate in the region (Kim et al. 2014; Yoo et al. 2014). During the raining season, precipitation mixes with air pollutants in a process called precipitation washout (Weiner and Matthews 2003). However, during the dry season, the conditions are suitable for human-induced biomass burning, bio-fuel combustion, and other human activities that enhance the build-up of pollutants in the air (Held et al. 2012).

Monthly comparison between historical air pollution (2005–2019) and air pollution during COVID-19 lockdown was made using boxplots (Fig. 2). The percentage changes in the air pollutants for the first 4 months of the year in all locations are presented in Table 1. Lagos declared total lockdown of activities on March 30 while partial lockdown was initiated on March 24 in both Kaduna and Port Harcourt (PH). A 12% and 32.4% increase was observed in NO_2 in January and February respectively in Lagos state. However, a decrease of −1.4% was observed in March. The small percentage change (0.3%) found in April could be attributed to the effect of the lockdown in the state. Similar reduction (1.7%) was found in SO_2 in the state compared with 54%

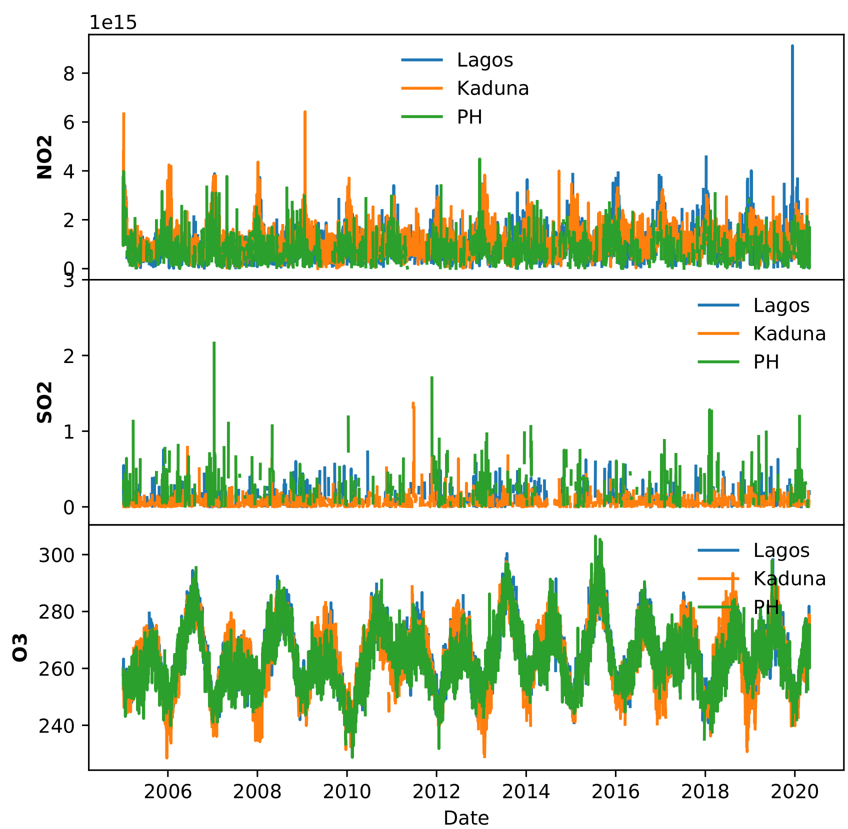

Fig. 1 Time series evolution of air pollutants in the locations under investigation from January 2005 to April 2020

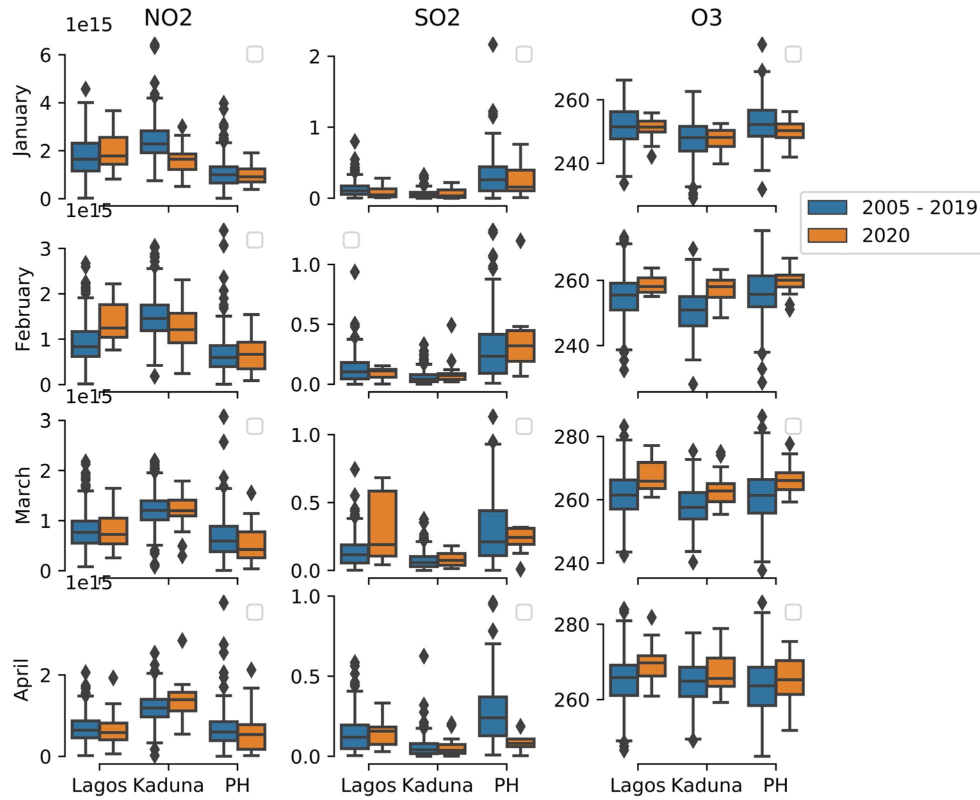

Fig. 2 Statistical distribution of air pollutants at different locations using box-plot

observed in March. Lagos is a coastal and commercial city with an estimated population of 17.5 million people within an area of 3577 km^2. The slight increase in the month of April, during the lockdown, could be attributed to the activities of essential industries, movement of essential personnels, local travels, and domestic activities in the state. Due to the large number of inhabitants in the state, reduction in levels of air pollutant is important both for the environment and health of the citizens.

The lockdown in Kaduna resulted in a smaller percentage change in SO_2 in March (10.5%) and April (8.9%) compared with January and February. However, the increase observed in Kaduna is higher than that obtained in Lagos for both NO_2 and SO_2. The small percentage increase observed in April in NO_2 and SO_2 for Kaduna could be attributed to other sources of burning fossil fuels such as bush burning. Being an agrarian state, bush burning which is carried out at the onset of the raining season began in late March and early April. Exceptions were made for industries in Kaduna during the lockdown; hence, contributions from industrial emissions cannot be ruled out. Furthermore, the power supply challenges in the country and the higher demand for it during the lockdown increased the use of gasoline generators in the region.

The most significant effect of the lockdown was observed in Port Harcourt. The early lockdown accounted for 21.9% and 37.3% reduction in NO_2 and SO_2 during March while a 1.1% and 215% reduction was reported in April. The significant reduction witnessed in Port Harcourt could be attributed to the impact of the lockdown on the oil-producing platforms in the region. The coastal city of Port Harcourt has been battling with black soot from oil refineries for many years (Yakubu 2018). The lockdown impacted on illegal refineries and gas flaring activities

Table 1 Percentage changes in air pollutants pre-2020 and 2020 period

.	NO_2			SO_2			O_3		
.	Lagos	Kaduna	PH	Lagos	Kaduna	PH	Lagos	Kaduna	PH
Jan	12.0	− 43.0	− 8.0	− 55.8	16.8	− 22.0	− 0.4	− 0.1	− 1.0
Feb	32.4	− 17.6	3.7	− 47.3	42.9	15.9	1.5	2.7	1.5
Mar	− 1.4	− 3.0	− 21.8	54.1	10.5	− 37.3	2.2	1.9	1.9
Apri	0.3	12.0	− 1.1	1.7	8.9	− 215.5	1.5	0.0	0.7

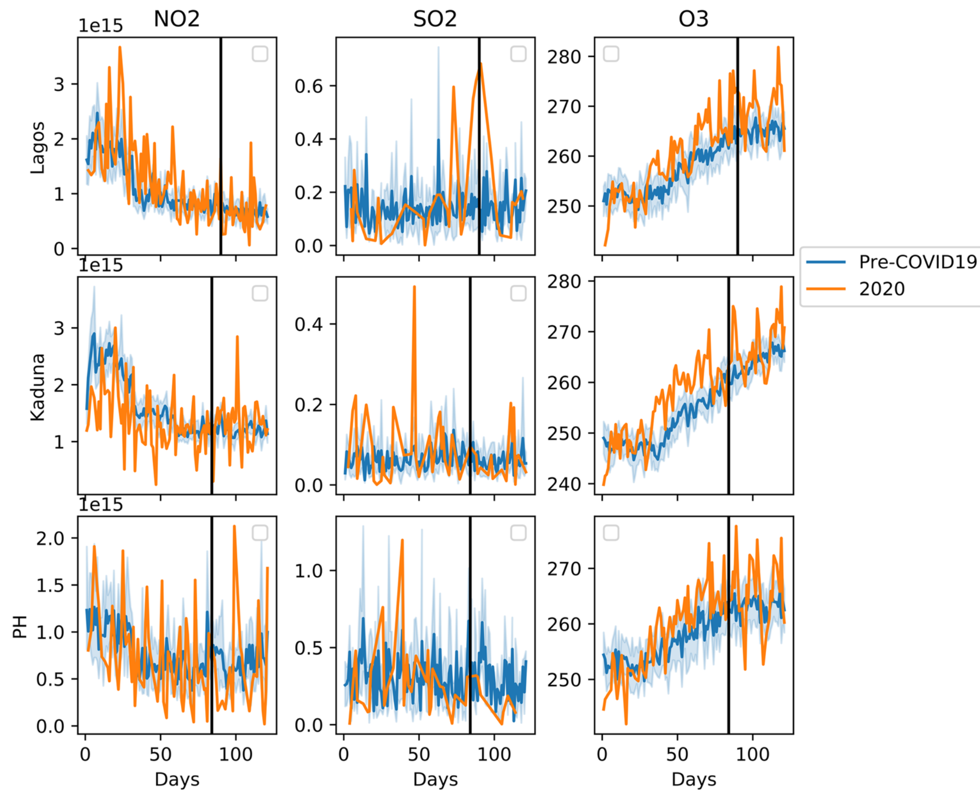

Fig. 3 Comparison between air pollutants in the first four months of 2020 with daily historical mean between 2015 and 2020. Black lines indicate beginning of lockdown in each location

of oil-producing companies as workers were unable to move during the period, hence a reduction in sales and consumption of fossil fuels.

The temporal evolution of air pollutants for the first 4 months of 2020 was compared with the daily historical mean between 2015 and 2019 (Fig. 3). Ozone in 2020 was found to have higher values than the historical mean. Similar trends, attributed to a decrease in nitrogen oxide concentration, have been observed in Brazil (Siciliano et al. 2020), Barcelona (Tobías et al. 2020), and India (Mahato et al. 2020; Sharma et al. 2020a). The greatest effect of lockdown on air pollution could be observed in NO_2 distribution over Port Harcourt. A sharp decrease was immediately created. A spike in NO_2 was observed in all three locations on April 1, 2020. This was due to a brief relaxation of lockdown which allowed for people to restock.

Conclusion

In this study, we have investigated the impact of COVID-19 lockdown on air quality in three locations within Nigeria. We compared the pollutant levels for the months of January to April 2020 with historical records to determine the level of change due to restricted mobility. Our results showed a reduction of 1.1, 3.0, and 21.8% change in NO_2 levels for Lagos, Kaduna, and Port Harcourt respectively during the period of the lockdown. Lagos and Kaduna saw an increase of 54 and 10% in SO_2 levels respectively during the same period. SO_2 levels decreased by 37% in Port Harcourt during the lockdown period. The differences were attributed to different levels of enforcement of the lockdown. In Lagos and Kaduna, limited industrial activities and use of fossil fuel generators for power generation are potential contributors to air pollution levels in the region. Reduction in industrial and transport activities during the pandemic is responsible for the reduced NO_2 levels in all the locations studied (Hopkins et al. 2009; Baumbach et al. 1995). Our results further showed that it is possible to reduce anthropogenic pollution in a developing country using policies and measures.

Air pollution is a clear danger that cannot be avoided, especially in major cities. There is the urgent need to create policies, take decisive actions, and educate the general public for the reduction of air pollution in our cities. This present study did not consider particulate matter, specific source attribution, and direct impact on health. Further studies considering particulate matter, volatile organic compounds, and other gases should be considered for the region.

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Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

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