The impact of COVID-19 pandemic on nitrogen dioxide levels in Nigeria

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The Coronavirus disease (COVID-19) has been transmitted worldwide over a very short time after it originated in China in December 2019. In an attempt to control its spread and reduce its health impacts, several countries including those in the African continent imposed restrictive measures that was termed "lockdown". The outcomes of this lockdown have been reported to be beneficial to air quality worldwide. The main objective of this study is to assess the impact of lockdown due to COVID-19 on nitrogen dioxide (NO_2) levels over six major cities in Nigeria. Maps extracted from satellite (Sentinel – 5P) were used to indicate the significant reduction in the level of NO_2 in the selected cities in Nigeria during two time-intervals, pre-lockdown (December, 2019) and during lockdown (April, 2020). The results show a significant reduction in NO_2 levels during the lockdown period compared with its levels during the pre-lockdown period in 2019. The reduction in NO_2 concentration levels during lockdown is likely due to less traffic, social distancing and restrictions on business and human activities. Although COVID-19 has negatively impacted the health and economic status of all regions worldwide, it has benefited some aspects of air quality in most countries including Nigeria. This indicates that anthropogenic activities may be managed to reduce air pollution and positively impact the health of human beings.

1   **The impact of COVID-19 pandemic on nitrogen dioxide levels in Nigeria**

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23   **Abstract**

24 The Coronavirus disease (COVID-19) has been transmitted worldwide over a very short time after
25 it originated in China in December 2019. In an attempt to control its spread and reduce its health
26 impacts, several countries including those in the African continent imposed restrictive measures
27 that was termed "lockdown". The outcomes of this lockdown have been reported to be beneficial
28 to air quality worldwide. The main objective of this study is to assess the impact of lockdown due
29 to COVID-19 on nitrogen dioxide (NO_2) levels over six major cities in Nigeria. Maps extracted
30 from satellite (Sentinel – 5P) were used to indicate the significant reduction in the level of NO_2 in
31 the selected cities in Nigeria during two time-intervals, pre-lockdown (December, 2019) and
32 during lockdown (April, 2020). The results show a significant reduction in NO_2 levels during the
33 lockdown period compared with its levels during the pre-lockdown period in 2019. The reduction
34 in NO_2 concentration levels during lockdown is likely due to less traffic, social distancing and
35 restrictions on business and human activities. There could be an element of uncertainty in the
36 results due to seasonality, as the comparison is done with a different season. However, the
37 magnitude of change due to lockdown is probably much higher than the seasonal variability.
38 Although COVID-19 has negatively impacted the health and economic status of all regions
39 worldwide, it has benefited some aspects of air quality in most countries including Nigeria. This
40 indicates that anthropogenic activities may be managed to reduce air pollution and positively
41 impact the health of human beings.
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44 **Keywords:** Covid-19, lockdown, air quality, Nitrogen dioxide, World Health Organization, 5-P

45 Sentinel, Africa, Health, Nigeria, pollution

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Introduction

50 The novel coronavirus (COVID-19) has changed human behavior and resulted in hundreds of

51 thousands of deaths, caused excessive loss of jobs, and reduced social and economic activities.

52 The first confirmed case of this deadly virus was seen in Wuhan province in China in December,

53 2019 before it spread across the globe and was declared by the World Health Organization (WHO)

54 as a pandemic in March 2020 (*Isaifan, 2020*). Severe Acute Respiratory Syndrome Coronavirus-2

55 (SARS CoV-2) has been confirmed as the pathogen responsible for COVID-19 (*Zhoua et al.*,

56 *2020*) which had previously caused Severe Acute Respiratory Syndrome (SARS) (*Peiris et al.,*

57 *2004*) and Middle East Respiratory Syndrome (MERS) (*Zaki et al., 2012*).

58 Nigeria reported the first case of COVID-19 on the 27th of February 2020, following the arrival of

59 an Italian citizen in Lagos from Europe (*Kalu, 2020*). Due to contact with the first case, a second

60 confirmed case was reported in Ogun State, and then more cases quickly emerged (*Kalu, 2020*).

61 Eventually, COVID-19 spread to all the States in the Federal Republic of Nigeria as reported by

62 the Nigerian Center for Diseases Control (NCDC) which showed that all the states in Nigeria had

63 one or more cases, with a confirmed fatality rate (CFR) of 3 %. Accordingly, the Federal

64 Government of Nigeria formed the Presidential Task Force (PTF), to oversee the pandemic. In the

65 course of this action, a 2-week lockdown was announced by the Nigerian Government on March

66 30th, 2020, in three states; Lagos, Ogun and Abuja, the first states hit by the virus before the

67 lockdown was further extended to the whole country. Afterwards, there have been a series of

68 extensions of this lockdown by both Federal and State Governments of Nigeria. Recently, the

69 lockdown has been gradually eased in phases to allow basic activities and normal business. The

70 World Health Organization (WHO) believes that lessons learnt from the Ebola crisis in 2014 in

71 Africa have improved the resilience of the African healthcare systems and their capacity to test

72 and successfully impose quarantine (*Fox, 2020*). Countries across the continent have garnered a

73 great deal of experience from tackling infectious diseases like polio, measles, Ebola, yellow fever,

74 influenza and many more (*Bruce-Lockhart, 2020*). Hence, the African governments were quick to

75 impose travel bans on airlines carrying passengers from Europe at the very beginning of the

76 pandemic while Europe and North American countries went into self-imposed economic and social

77   lockdown at a later stage. Economically, the UNECA reckons that Nigeria could suffer a $19

78   billion hit, largely from lost oil revenues (*Fox, 2020*).

79   During the long lockdown in Nigeria, many economic and social activities were brought to a halt;

80   commercial activities; vehicular movements (private and governmental owned); most industrial

81   activities, especially in the oil rich cities of the Delta which account for the greater percentage of

82   emissions in Nigeria, and other human activities which invariably reduced anthropogenic

83   emissions. Air pollution (release of harmful substance to the atmosphere in a concentration that

84   could pose serious threats to humans, animals and plants) is a serious concern to the world. Air

85   quality can be affected by natural sources such as volcanic eruptions, and natural disasters, and

86   by anthropogenic sources such as the combustion of fossil fuels (diesel, gasoline, and oil) used for

87   energy production and by industrial activities related to construction, mining, cement

88   manufacturing, and smelting (*Li and Mallat,2018; Al-Thani,et al.,2018; Al-Thani et al.,2020*).

89   Several studies have been carried out to assess the impacts of air pollution on humans as it poses

90   a serious health risk. For instance, the exposure to an elevated amount of NO_2 has been associated

91   with hypertension illness (*Shin et al., 2020*). Several studies have shown an increased rate of heart-

92   related diseases due to air pollution exposure (*Li et al., 2016; Logue et al., 2012*). Nwachukwu et

93   al., (2012) reported on the effect of air pollution on inducing several diseases for the people living

94   in the vicinity of Rivers State in Nigeria by comparing epidemiological data to air quality data.

95   The results showed that a total of 30,435 cases of illness (e.g., pertussis, pulmonary tuberculosis,

96   cerebrospinal meningitis (CSM), pneumonia, measles, chronic bronchitis, and upper respiratory

97   tract infection (URT)) were reported between 2003 and 2008, of which 61 patients died.

98   There have been reports on the reduction of air pollution since the advent of coronavirus in various

99   cities of the world. Isaifan has initially reported on the air quality status in China before and after

100 the coronavirus crisis (*Isaifan, 2020*). It has been shown that shutting down industrial activities

101 which are considered intense sources of air pollution, in response to the COVID-19 pandemic

102 emergency lockdown may have saved more lives by preventing air pollution than by preventing

103 infection with the virus. In India, Gupta et al., (2020) analyzed various environmental impacts due

104 to the lockdown as prevention for COVID-19 throughout India. They observed a significant

105 reduction in the main air pollutants such as nitrogen dioxide, carbon monoxide, sulphur dioxide,

106 ozone and particulate matter, hence the positive impact of containment of air quality. In India,

107 Sharma et al., (2020) investigated the impact of COVID-19 on restricting activities by analyzing

108 the concentrations of six criteria pollutants, PM_{10}, $PM_{2.5}$, CO, NO_2, ozone and SO_2 during March

109 16th to April 14th from 2017 to 2020 in 22 cities covering different regions of India. They reported

110 an overall 43, 31, 10, and 18% decreases in $PM_{2.5}$, PM_{10}, CO, and NO_2; respectively in India during

111 lockdown period compared to previous years while, there were 17% increase in O_3 and negligible

112 changes in SO_2.

113 Using ground-based monitoring stations, IQAir Air Visual (2019) World air quality assessed the

114 impact of COVID-19 restrictions on $PM_{2.5}$ levels for 10 major cities around the world. The

115 reduction in $PM_{2.5}$ was observed in 9 of the 10 cities compared to the same period in 2019. The

116 best air quality was recorded in Wuhan in February and March 2020. Delhi air quality dropped

117 from 68% in 2019 before the lockdown period to 17% during the lockdown period, while the

118 longest period of clean air was recorded in Los Angeles in compliance with WHO air quality

119 guidelines.

120 The study reported here explored the implications of the lockdown due to COVID-19 on

121 Nigerians' air quality, and more specifically on NO_2 levels. The chosen cities are Lagos, Ibadan,

122 Abuja, Kano, Owerri and Onitsha which are distributed along different locations in the country. In

123   addition, these cities are among the top major inhabited cities in Nigeria based on their

124   demography.

Lagos and Ibadan

126   Lagos State lies in the southwestern part of Nigeria within latitudes 6º 23′ N and 6º 41′ N and

127   longitudes 2º 42′ E and 3º42′E. Lagos is the most populous city in Nigeria and in all Africa, and

128   is considered the financial center of the metropolis. Fifty percent of Nigeria's industrial activities

129   including 300 industries in 12 industrial Estates are located in the Lagos area. The high

130   urbanization and industrial growth rate in Lagos has made it one of the most densely-populated

131   regions on earth with about 9.3 million inhabitants according to 2006 Census (*Adesuyi et al,2015*).

132   The city has a tropical climate with an average relative humidity of 79%. The mean monthly

133   temperature ranges from 23 – 32ºC. Being located in a coastal area and influenced by strong sea

134   based disturbances, Lagos experiences an average wind speed of 4.3 km/h (*Komolafe et al, 2014*).

135   Lagos metropolis has been experiencing air pollution problems in all its severity over the past

136   decades (*Njoku et al.,2016*). Sources of air pollution include traffic (vehicle exhaust), industrial

137   sectors (from brick making to oil and gas production), power plants and generating sets, cooking

138   and heating with solid fuels (e.g. coal, wood, crop waste), forest fires and open burning of

139   municipal waste and agricultural residues (*Akanni ,2010; Komolafe et al.,2014*).

140   Ibadan is the capital of Oyo State, South West Nigeria. Ibadan is positioned on longitude 3°53E of

141   Greenwich Meridian and latitude 7°23N of the equator. This ancient city is located close to forest

142   and grassland boundary of south western Nigeria and about 145 km North East. Due to its location,

143   Ibadan serves as a meeting point for people and products from forest and grassland areas (*Rowland*

144   *Ana, 2015*). The city of Ibadan is known to be the third largest metropolitan area in Nigeria after

145   Lagos and Kano. This is because it is one of the fastest urbanizing cities in Nigeria. The increase

146   in urbanization is attributed to the provision of better economic opportunities due to setting up of

147   factories and industries, which has led to migration of population from rural regions to the city. As

148   a result, people spread to the peripheral areas of the urban fringes (*Rowland Ana, 2015*).

149   **Kano**

150   Kano is the capital of Kano State, Nigeria which lies between latitude 11^0 55' 23.93'N to 12^0

151   3'53.10'N and longitude 8^0 27'42.26'E to 8^0 36'41.62'E and is 1549 feet above sea level. The

152   estimated area of Kano metropolis increased from 122.7 square kilometers in 1962 to 154.6 square

153   kilometers in 1981, an increase of about 25% based on the average expansion rate of two square

154   kilometers per annum (*Na'Abba, 2002*).

155   Kano is referred to as the Center of Commerce in the Country due to its long flourished marketing

156   activities. This is based on the fact that marketing and trading has been the dominant economic

157   activities in Kano. However, the land is mostly exploited by urban agriculture through waste water

158   utilization to sustain daily needs. The average temperature is a bit hot, even during the cool

159   Harmattan period, the minimum temperature hardly falls below 11^oC, whilst the monthly average

160   temperature is not less than 20^oC. During the hot season, usually Mid – March to Mid-May, the

161   maximum temperature reading can reach as high as 40^oC. The average temperature for these hot

162   months may range between 30^oC and 32^oC (*Adzandeh et al., 2014*).

163   **Abuja**

164   Abuja is the federal capital of Nigeria and is located at 6°45" longitude and 7°45" E from

165   Greenwich and at 8°25" latitude and 9°25" N from the equator. It is bounded on the north by

166   Kaduna State, on the east by Nassarawa State, on the west by Niger State and on the south by Kogi

167   State. The topography of the region is characterized by the presence of several peaks which

168   constitute the highest part of the region; located at 760 m above sea level (*Balogun, 2001*).

169 Climatically, the region has a high intensity of precipitation which reaches 1,631.7 mm per year

170 and an average annual temperature between 25.8^0C and $30.2°C$. Abuja has an international airport

171 and is linked to other Nigerian cities by a network of highways.

172 **Owerri and Onitsha**

173 Owerri is the capital of Imo State, located in south-eastern Nigeria. It is bounded on the south by

174 Nekede, on the north by Amakohia, on the east by Egbu, on the northeast by Uratta, on the

175 southeast by Naze, and on the northwest by Irette. The main activities of the inhabitants are public

176 functions, commerce and agriculture (*Obionu, 2007*). The average temperature is around $27°C$

177 ((*Obionu, 2004*). The vegetation is typically tropical rainforest with some parts of Guinean

178 savannah as a result of environmental degradation through pollution.

179 The city of Onitsha is located on a vast flood plain on an altitude of 26 m above sea level between

180 latitudes $6°5'$to $6°11'N$ and longitudes $6°45'$to $6°53'E$. The climate type is equatorial tropical with

181 dry and wet seasons. The rainy season extends from March to October and the dry season begins

182 from November to February. The region is located in the rainforest belt, with an average rainfall

183 of 2100 mm. According to the World Bank, Onitsha is the most polluted city in the world for air

184 quality as measured by the concentration of small particles (PM_{10}). The main factors contributing

185 to air pollution are waste combustion, emissions from old cars and the heavy use of fossil fuels for

186 cooking (*WHO, 2016*).

187 The combustion of fossil fuels in these selected cities generates large quantities of nitrogen dioxide

188 (NO_2), but traffic is considered the main source. NO_2 causes cellular inflammation, bronchial

189 hyper-reactivity and respiratory problems, reportedly causing the death of about 4.6 million people

190 each year (*Muhammad et al., 2020; Latza et al., 2009*). To investigate the air quality impact of the

191 lockdown due to COVID-19, each city's tropospheric column of nitrogen dioxide was analyzed.

192   This study compares the levels of NO_2 density before the advents of the first reported case of

193   COVID-19 in Nigeria and its levels during the lockdown in selected cities to assess its impact on

194   the air quality of Nigeria.

195

196   **Materials & Methods**

197   For NO_2 concentration in the troposphere (from surface up to ~10 km), the Sentinel-5 Precursor

198   space-borne satellite (spatial resolution of 5.5 km) was used which is operated and managed by

199   the European Commission under the "Copernicus" program. The satellite operates in a sun-

200   synchronous orbit at 824 km and an orbital cycle of 16 days. The satellite carries a TROPOspheric

201   Monitoring Instrument (TROPOMI) which provides a (near-) global coverage of air pollution

202   caused by NO_2 and other pollutants such as O_3, SO_2, CO, CH_4, and aerosols. (*Veefkind et al.,*

203   *2012*).

204   This study necessitated the extraction of NO_2 data from Sentinel 5P Near Real Time level 2 satellite

205   images achieved in NetCDF format and captured for specific exposure durations in 2 separate

206   months (December 2019 and April 2020). From the sentinel 5P satellite images, the extracted NO_2

207   data were used to compare the trend of NO_2 spread in the atmosphere before and during the

208   COVID-19 lockdown in the Nigerian cities selected (Lagos, Owerri and Onitsha, Abuja and

209   Kano).

210   The Panoply 4.11.2 application was used to process the Network Common Data Format files

211   (NetCDF) to raster images using two dimensions latitude and longitude (in that order) and scaled

212   to reflect the proper NO_2 concentration, ArcMap 10.5 was used to analyze the NO_2 sentinel 5P

213   satellite images, projecting then to the scale of the selected cities, likewise, applying standard

214   deviation stretch to address the image stretch property as a result of the analysis carried out on the

215   images.

216   For the secondary data which includes Sentinel 5P NO_2 Satellite imagery (Table 1) covering the

217   study area in NetCDF file format were obtained from Copernicus website and the Tropospheric

218   column of Nitrogen dioxide file for the months of April and December was used in this research

219   work.

220   In addition, administrative boundaries (National and State boundary shape files) of Nigeria was

221   sourced from DIVA-GIS website a repository of free spatial data. The resultant image provided

222   information on NO_2 concentrations within the study areas. The maps were scaled to 1:60,000.

223   Additional secondary data were also obtained from a number of literatures ranging from text

224   books, research articles and journal papers. Table 1 shows the various data types used in this

225   research and their sources.

226   Sentinel 5P Near Real Time Level 2 images for the months of December 2019 and April 2020 for

227   the study area, were plotted in Panoply. The tropospheric vertical column of nitrogen dioxide of

228   each NetCDF file was plotted using the georeferenced longitude and latitude color contour plot.

229   Using the scalar unit of micromole per meter square with a scale range minimum of 0 and

230   maximum of 100, the plotted images were later exported to tagged image file format for further

231   analysis in ArcMap.

232   The Tagged Image file (TIF) plotted in Panoply environment was processed in ArcMap, the image

233   was georeferenced and projected to UTM 31; clipped using the Nigeria National Boundary;

234   overlaid with the State boundary and State capitals.

235   **Results**

236   Figure 1 shows the map of Nigeria and highlights the areas included in this study. Table 2 shows

237   the main features of the cities chosen for this study. Figure 2 shows the demographic distribution

238   of confirmed cases in Nigeria. It can be seen that highly dense and populated areas have witnessed

239   more infections than other regions as expected. Moreover, the demographic distribution of infected

240   cases show that male confirmed cases were dominant over female's with 9117 cases for male and

241   4347 female which accounted to 68% and 32%; respectively (Table 3 and Figure 3). Moreover,

242   Fig. 3 reveals that the most affected age group is 31 – 40 which makes up about 24% of all age-

243   group cases.

244   Table 4 shows the total registered cases with COVID-19 globally and the new cases in the last 24

245   hours as per the 10th of June, 2020. It can be seen that Africa has the least number of cases with

246   2.03% out of all registered cases globally. The same can be seen from the number of deaths which

247   amounted to 0.86% of global deaths by COVID-19. Moreover, Fig. 4 shows the epidemic curve

248   of confirmed cases in Nigeria. In addition, figures in Table 5 shows Situation updates in numbers

249   with the total cases (new cases in the last 24 hours) by June 10th, 2020.

250

251   From the analysis of the map in Fig. 5 (B), it can be seen that nitrogen dioxide pollution has been

252   widely present around the city of Lagos and its surroundings with high concentrations reaching

253   156.9 $\mu mol/m^2$ and above 575.7 $\mu mol/m^2$, with Ikeja the capital of the city recording 505.9305

254    $\mu mol/m^2$. Oyo State generally has a much lower nitrogen dioxide emissions between -52.36

255    $\mu mol/m^2$ to 471 $\mu mol/m^2$ compared to Lagos state, while Ibadan town has a concentration of

256   453.58 $\mu mol/m^2$ at the time before lockdown. Nevertheless, the map representing lockdown period

257   (Fig. 5 A) shows a visible decrease in nitrogen dioxide concentrations, with Ikeja measuring a

258   negative value of -60.41 $\mu mol/m^2$ representing a decrease in Nitrogen dioxide concentration. Lagos

259 overall concentration is between -95.15 $\mu mol/m^2$ and -25.05 $\mu mol/m^2$. This indicated significant

260 decrease in activities that generate NO_2 due to lockdown restrictions.

261 The distribution of nitrogen pollution in the city of Kano is less severe compared to Lagos, only

262 Kano town and its vicinity recorded a high concentration range between 471.03 $\mu mol/m^2$ and

263 366.34 $\mu mol/m^2$ while the rest have recorded values between -50.46 $\mu mol/m^2$ and 191.84 $\mu mol/m^2$

264 before lockdown as shown in Fig. 6 (B) which is representative of December 2019. Whereas,

265 during the containment period April 2020 (Fig. 6 A), NO_2 pollution has reduced drastically in the

266 entire Kano area, with values ranging between -49.59 $\mu mol/m^2$ to 55.70 $\mu mol/m^2$ while Kano town

267 records values at about -37.47 $\mu mol/m^2$.

268 Figure 7 (B) shows that NO_2 has high concentrations in the city of Abuja and in the north of the

269 city with the presence of several spots with high NO_2 concentrations during December 2019.Abuja

270 city and northwest of Abuja city area show NO_2 concentration values ranging between 296.54

271 $\mu mol/m^2$ to 575.73 $\mu mol/m^2$. Other neighbouring towns southward Abuja marked values between

272 17.35 $\mu mol/m^2$ to 157 $\mu mol/m^2$. On the other hand, the results in Fig. (7 A) do not show any spots

273 with NO_2 pollution due to lockdown measures, therefore accounting for a low NO_2 reading

274 between -3.53 $\mu mol/m^2$ and 33.19 $\mu mol/m^2$ within the Federal Capital Territory, while Abuja

275 Town accounts for readings around 26.23 $\mu mol/m^2$.

276 Based on the analysis of the results presented in Figure 8, it is found that Onitsha area is the most

277 polluted with the presence of several scattered spots representing NO_2 pollution throughout the

278 region (Fig. 8 B). The atmosphere in Onitsha town is charged with about 296.5 $\mu mol/m^2$ while

279 Owerri town measures 471.03 $\mu mol/m^2$, other places measure as high as 156.9 $\mu mol/m^2$. Fig. (8

280 A) shows a significant drop in NO_2 concentrations during the lockdown period. Onitsha records

281   15.94 µmol/m^2 (94%) reduction while other places within the state measure 35.01 µmol/m^2 (highest

282   within the state) while Owerri town records 38.11 µmol/m^2, with lowest value of -18.17 µmol/m^2

283   and highest value of 60.29 µmol/m^2 within Anambra state. It is noted that the pollution have fallen

284   further in the area with the persistence of a few spots with high NO_2 concentrations, which is

285   normal since this city is one of the most polluted in terms of air pollution in the world.

286   **Discussion**

287   COVID-19 is a major pandemic and global issue that caused severe health, social and economic

288   impacts in every country. Nevertheless, Africa has been reported to have had less impact due to

289   its early measures taken to abate this disease due to its recent experiences in similar infectious

290   disease over the past decades.

291   This study analyzed the impact of COVID-19 on NO_2 concentration in six major cities in Nigeria;

292   namely: Lagos, Ibadan, Kano, Abuja, Owerri and Onitsha. To understand the impacts of the

293   lockdown conditions, Sentinel 5P Near Real Time level 2 Nitrogen dioxide (NO_2) satellite images

294   extracted for specific durations in 2 separate months (December, 2019 and April, 2020) as shown

295   in Figures 5-8. The results show significant reduction in NO_2 concentrations over the cities under

296   investigation due to the lockdown measures taken by the government. These reductions in NO_2

297   could be due to restrictions on sources of anthropogenic activities such as transportation and

298   commercial activities. Moreover, the observations related to the dramatic reduction in air polluting

299   emissions in Nigeria are in agreement with what has been reported for other regions globally. It is

300   worth noting that NO_2 emissions can be affected by seasonality. However, more data is required

301   to cover the same periods to avoid the influence of seasonality changes between winter and spring.

302   Recently, Fuwape, et al., (2020) recently assessed the impact of COVID-19 lockdown on air

303   quality in three locations within Nigeria; in doing these, they compared historical air pollution

304   (2005–2019) and air pollution during COVID-19 lockdown (especially for the months of January

305   to April, 2020) to determine the level of air quality change using boxplots. Their results revealed

306   a reduction of 1.1, 3.0, and 21.8% change in NO_2 levels for Lagos, Kaduna and Port Harcourt;

307   respectively during the period of the lockdown. In addition Lagos and Kaduna saw an increase of

308   54 and 10% in SO_2 levels respectively during the same period. There was also a reduction of SO_2

309   levels by 37% in Port Harcourt during the lockdown period. They attributed this differences

310   between 2005-2019 (before lockdown period) and January to April, 2020 (during lockdown

311   period) to be due to different levels of enforcement of the lockdown in the different study locations.

312   Further detailed maps of NO_2 levels in Wuhan, China from the 1st of January through the 25th of

313   February of last year (2019) show the region covered with intense dark layers indicating much

314   higher concentrations of NO_2. The images were compared with the same period in 2020 after the

315   breakout of coronavirus where reduced levels of NO_2 have been observed (*Isaifan, 2020)*.

316   Recently, Bashir et al., (2020) studied the correlation between the fast spread of COVID-19 and

317   the climate indicators such as temperature and humidity in New York City in USA (*Bashir et*

318   *al.,2020*). They found a correlation between the minimum and average temperatures with the

319   spread of COVID-19 indicating that higher temperature serves as a driver for the COVID-19.

320   Moreover, humidity was found to be another factor for the spread of COVID-19 as it contributed

321   towards the rapid transmission of COVID-19 within New York City. In addition, the population

322   density (8.54 million people, 26,403 people per square mile) and being a cultural and financial

323   capital of the world, New York City experiences large amount of global travel all of which plays

324   a role in rapid transmission of Covid-19 (*Bashir et al.,2020)*. Similarly, the higher densely

325   populated cities in Nigeria such as Lagos had extremely higher levels of pollution, and hence more

326   confirmed cases and deaths are expected.

Conclusions

328   In this study, the variation of NO_2 which was collected from the satellite (Sentinel – 5P) was used

329   to indicate the significant reduction in the level of NO_2 in six major cities in Nigeria. The

330   observations compare the level of NO_2 emissions before and after lockdowns. Two main durations

331   were compared (December, 2019 and April, 2020). NO_2 emission in the various cities under study

332   shows a significant drop after the first coronavirus was announced in Nigeria, this could be due to

333   restriction of vehicular and commercial activities as also reported in various cities across the world.

334   There could be an element of uncertainty in the results due to seasonality, as the comparison is

335   done with a different season. However, the magnitude of change due to lockdown is probably

336   much higher than the seasonal variability. The outcomes indicated that the novel coronavirus is

337   considered a blessing in disguise. The current status of air quality in terms of lower NO_2

338   concentrations has significantly improved. The impact might be temporary but there is a very good

339   opportunity for all nations to learn about the outcomes of lockdown with minimum impact on

340   economy.

341

Table Captions

343   **Table 1.** Data type and sources of data collected for this research.

344   **Table 2**. Population, area, and population density in each of the cities included in this work as

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349   **Table 5.** Situation updates in numbers. Total positive cases (new cases in the last 24 hours) by

350   June 10th, 2020.

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352   **Figure Captions**

353   **Figure 1**. Map showing Nigeria and areas included in this study.

354   **Figure 2**. COVID-19 outbreak status in Nigeria. Number of positive cases.

355   **Source**: Nigerian Centre for Diseases Control (NCDC) data as at June 10th, 2020

356   **Figure 3.** Age-Sex distribution of confirmed cases.

357   **Source**: Nigeria Centre for Disease Control (NCDC) 2020

358   **Figure 4.** Daily epidemic curve of confirmed cases**.**

359   **Source**: Nigeria Centre for Disease Control (NCDC) 2020**.**

360   **Figure 5.** Nitrogen dioxide concentration levels over Lagos and Ibadan during lockdown period

361   **April, 10-18, 2020 (A)** and pre-lockdown period **Dec., 10-14, 2019 (B).**

362   **Figure 6.** Nitrogen dioxide concentration levels over Kano during lockdown period **April, 10-**

363   **18, 2020 (A)** and pre-lockdown period **Dec., 10-14, 2019 (B).**

364   **Figure 7.** Nitrogen dioxide concentration levels over Abuja during lockdown period **April, 10-**

365   **18, 2020 (A)** and pre-lockdown period **Dec., 10-14, 2019 (B).**

366   **Figure 8.** Nitrogen dioxide concentration levels over Owerri and Onitsha during lockdown

367   period **April, 10-18, 2020 (A)** and pre-lockdown period **Dec., 10-14, 2019 (B).**

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Data type and sources of data collected for this research.

2 **Table 1**. Data type and sources of data collected for this research.

No.	Name Type	Data Source	Date Acquired	File Name	Filename Extension
1	Nitrogen dioxide tropospheric column	http://s5phub.copernicus.eu/dhus/#/home	April 2019, December 2019, April 2020	NetCDF	.nc
2	National and State Boundary	http://diva-gis.org/data	March, 2020	Shape file (Polygon)	.shp
3	State Capital	Google Earth Pro	March, 2020	Keyhole Markup Language Zipped	Kmz /Kml

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Population, area, and population density in each of the cities included in this work as per Worldometer census data.

1   **Table 2.** Population, area, and population density in each of the cities included in this work as

2   per Worldometer census data.

City	Population (2020)	Area (Km²)	Population density (person/Km²)
Lagos	9,000,000	1,171	7,685
Kano	3,626,068	449	8,076
Ibadan	3,565,108	3,080	1,158
Abuja	590,000	1,769	334
Owerri	215,038	551	390
Onitsha	561,066	52	10,789

Demography and most affected age group by June 10th, 2020.

2   **Table 3.** Demography and most affected age group by June 10th, 2020.

Demography		Most affected age group
Male	Female	31-40
9117 (68%)	4347 (32%)	(24%)

Situation in numbers by WHO Region. Total positive cases (new cases in the last 24 h), and total deaths (new cases in the last 24 h) by June 10th, 2020.

2   **Table 4.** Situation in numbers by WHO Region. Total positive cases (new cases in the last 24 h),

3   and total deaths (new cases in the last 24 h) by June 10th, 2020.

Globally	**7145539**	**cases (105621)**	**408025**	**deaths (3629)**
Africa	145287	cases (4789)	3493	deaths (141)
Americas	3415174	cases (48923)	185863	deaths (1913)
Eastern Mediterranean	677338	cases (18724)	15246	deaths (333)
Europe	2321147	cases (17786)	185537	deaths (866)
South-East Asia	392674	cases (14556)	10741	deaths (365)
Western Pacific	193178	cases (843)	7132	deaths(7132)

5   **Source**: Situation Report–142 Data as reported by WHO from National Authorities by 10:00 CEST, by

6   June 10th, 2020

Situation updates in numbers. Total positive cases (new cases in the last 24 hours) by June 10th, 2020.

2   **Table 5.** Situation updates in numbers. Total positive cases (new cases in the last 24 hours)
3   by June 10th, 2020.

Sample tested	Confirmed cases	Affected States	Discharged cases	Confirmed Fatalities
82935 (2987)	13464 (663)	36 (0)	4206 (166)	365(4) 3% CFR

Figure 1

Map showing Nigeria and areas that have been included in this study.

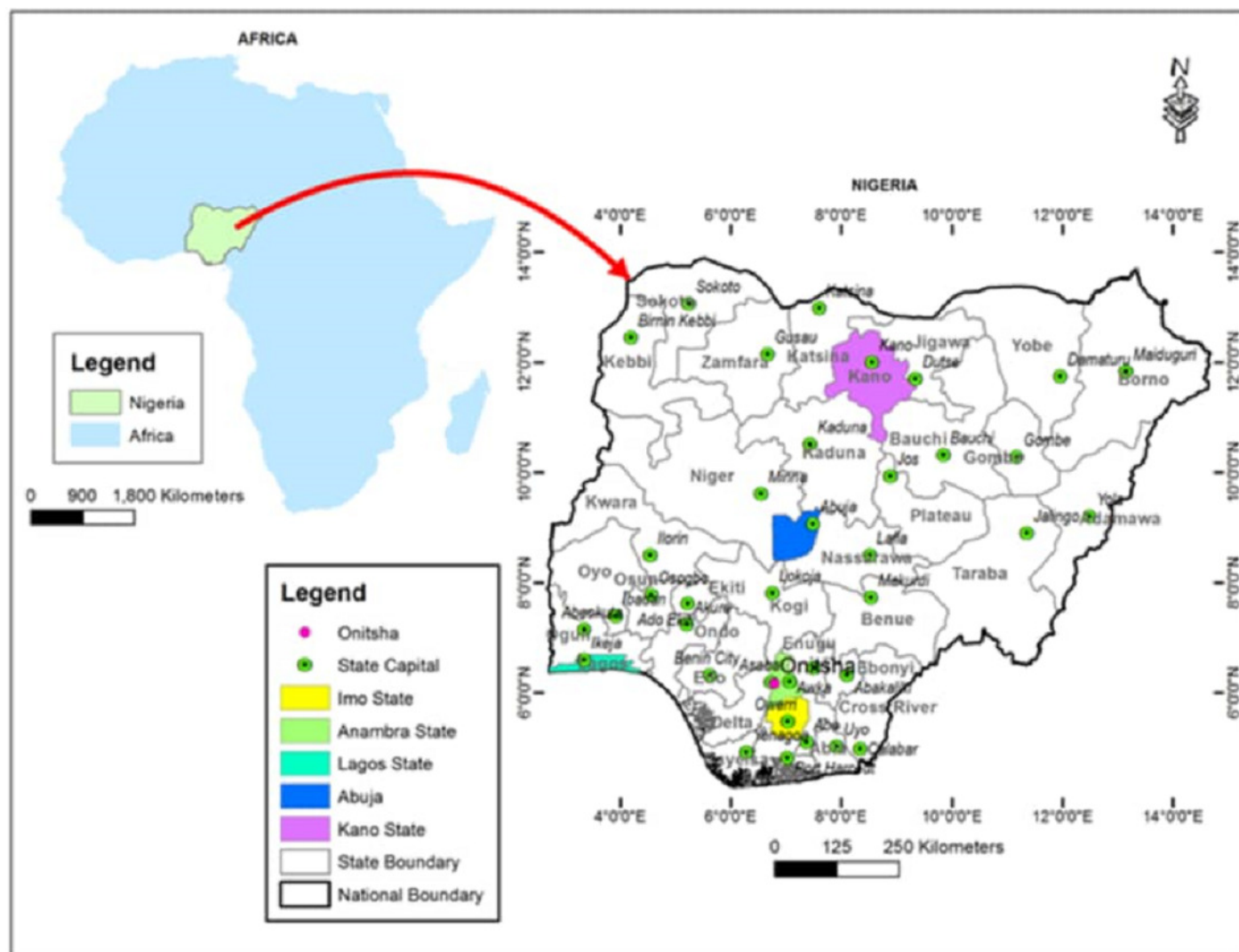



Figure 2

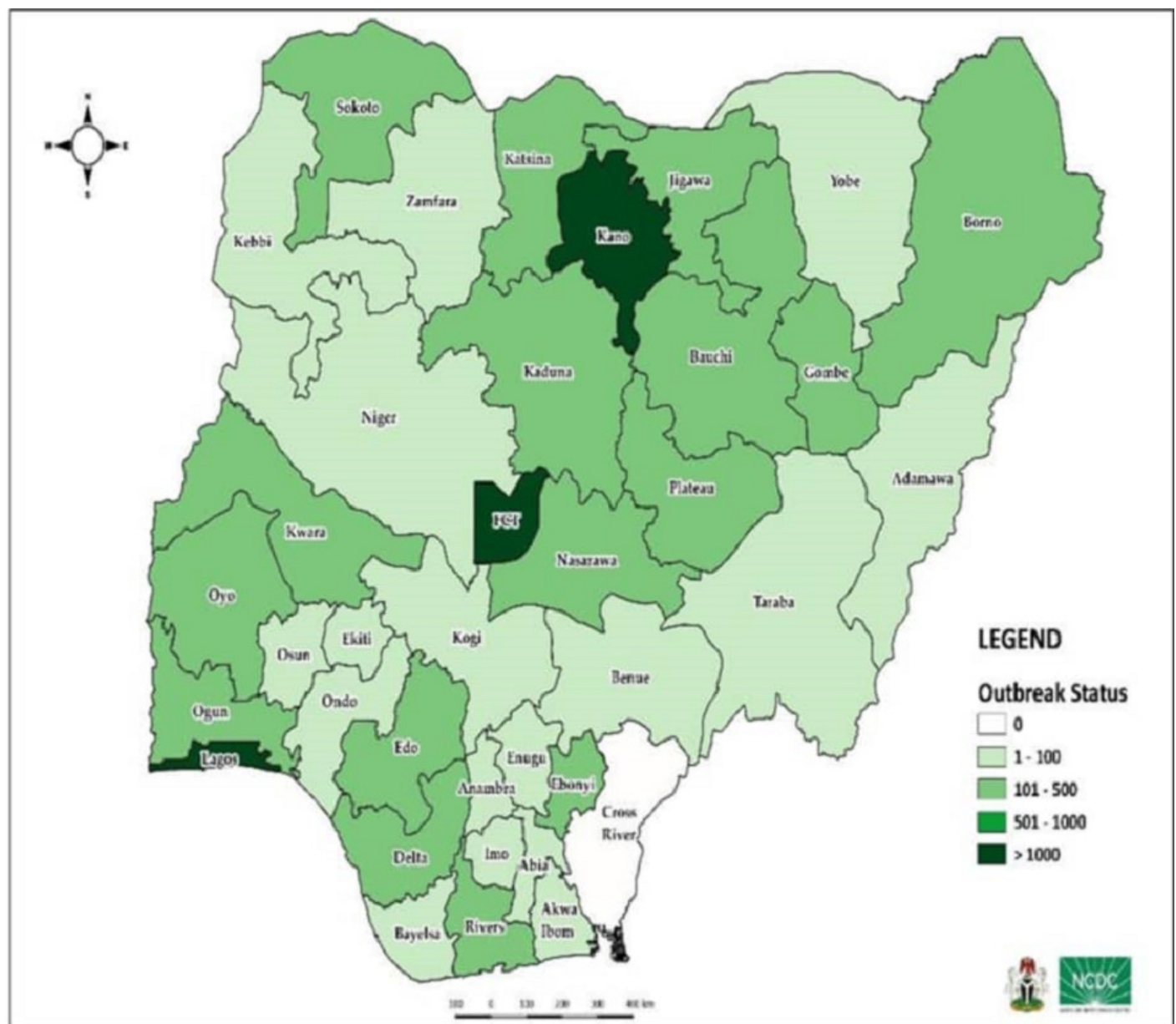
COVID-19 outbreak status in Nigeria. Source: Nigerian Centre for Diseases Control (NCDC) data as of June 10th, 2020.

Source: Nigeria Centre for Disease Control (NCDC) 2020.

Figure 3

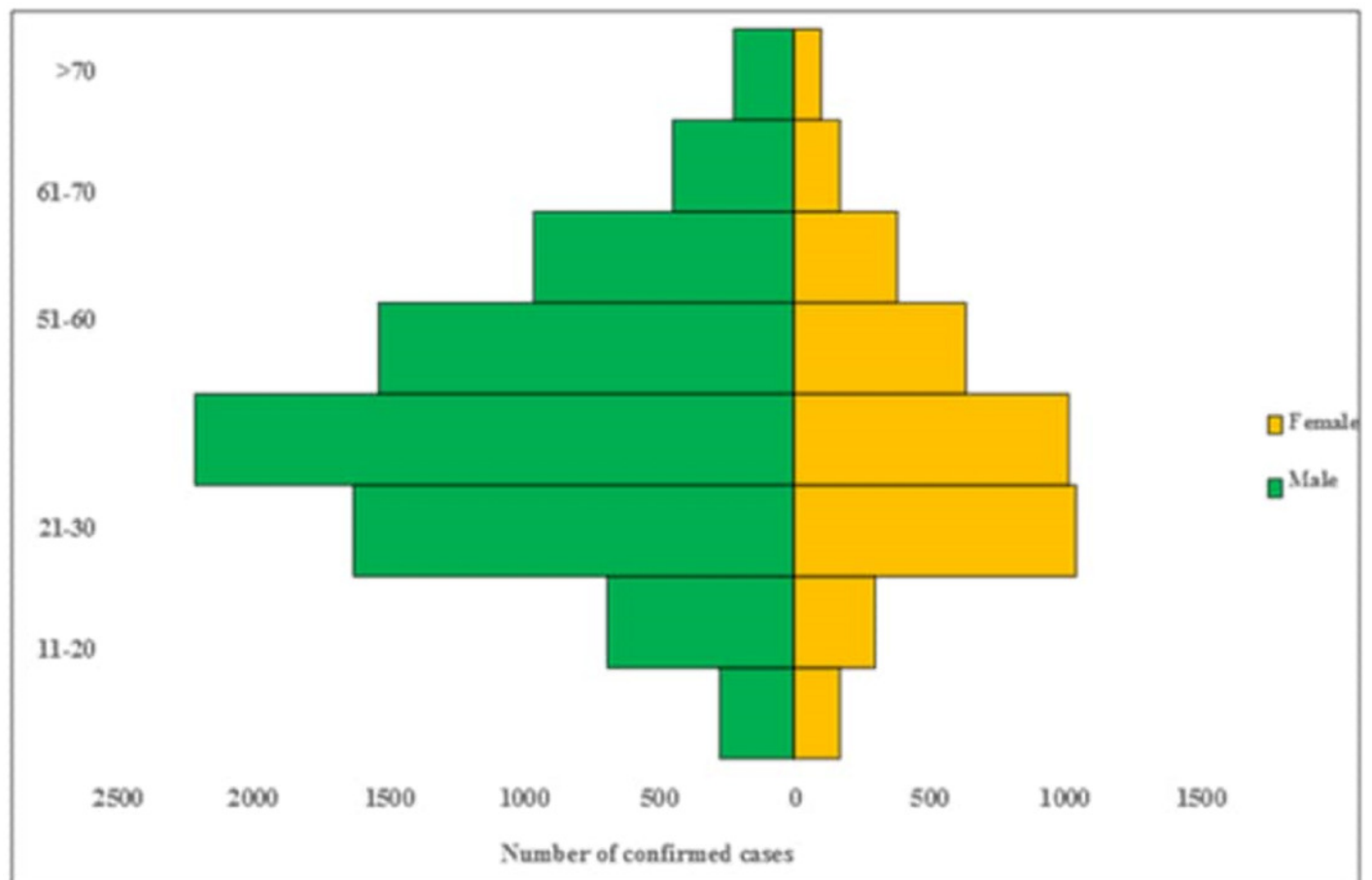
Age-Sex distribution of confirmed cases.

Source: Nigeria Centre for Disease Control (NCDC) 2020.

Figure 4

Daily epidemic curve of confirmed cases.

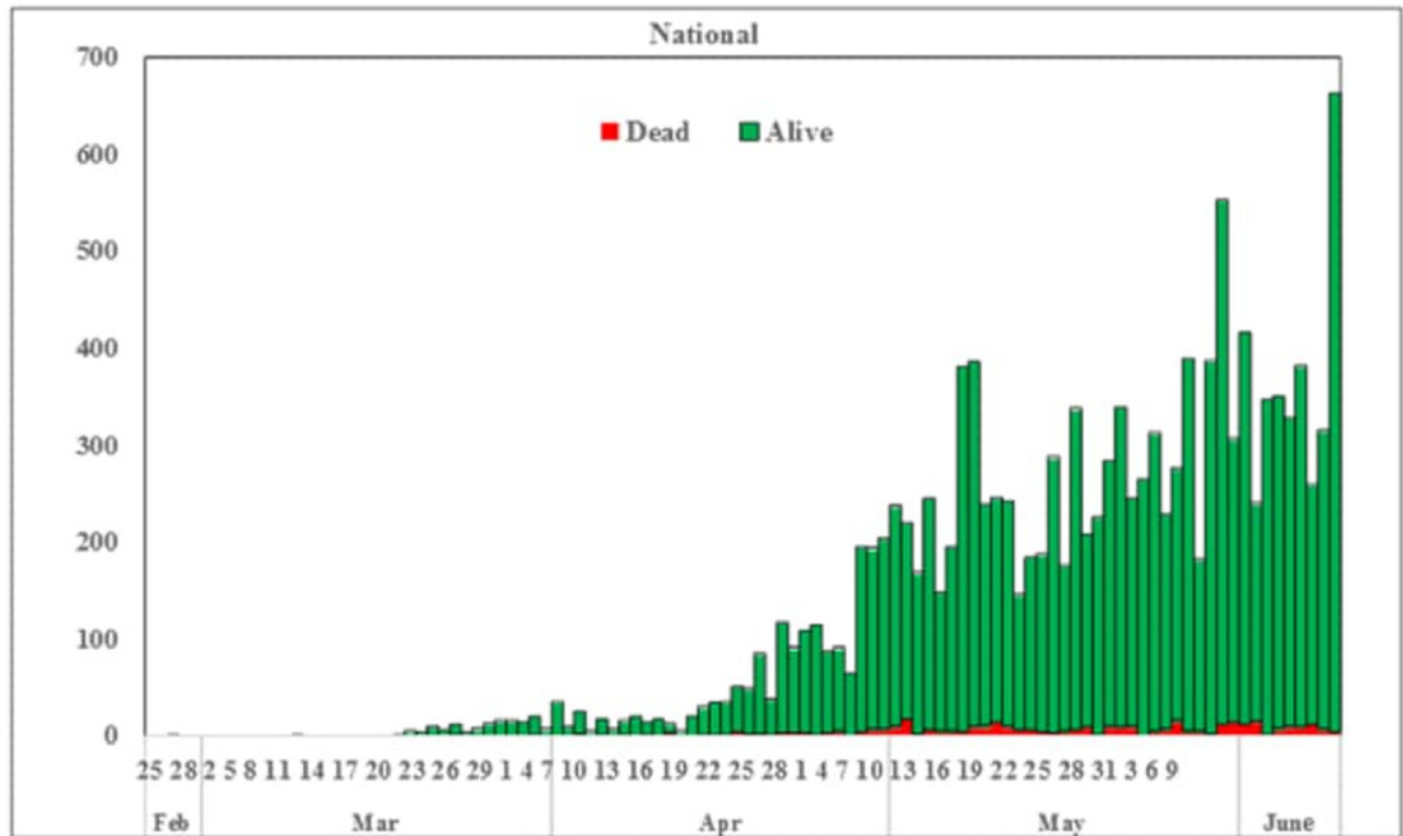



Figure 5

Nitrogen dioxide concentration levels over Lagos and Ibadan during lockdown period April, 10-18, 2020 (A) and pre-lockdown period Dec., 10-14, 2019 (B).

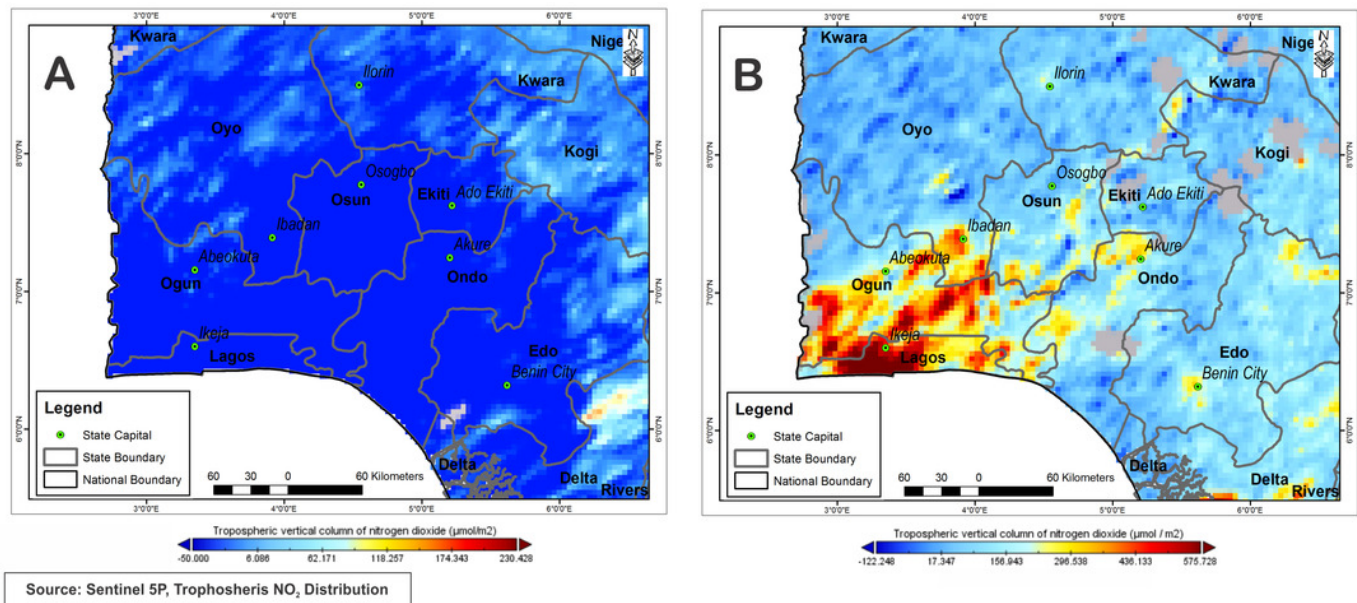



Figure 6

Nitrogen dioxide concentration levels over Kano during lockdown period April, 10-18, 2020 (A) and pre-lockdown period Dec., 10-14, 2019 (B).

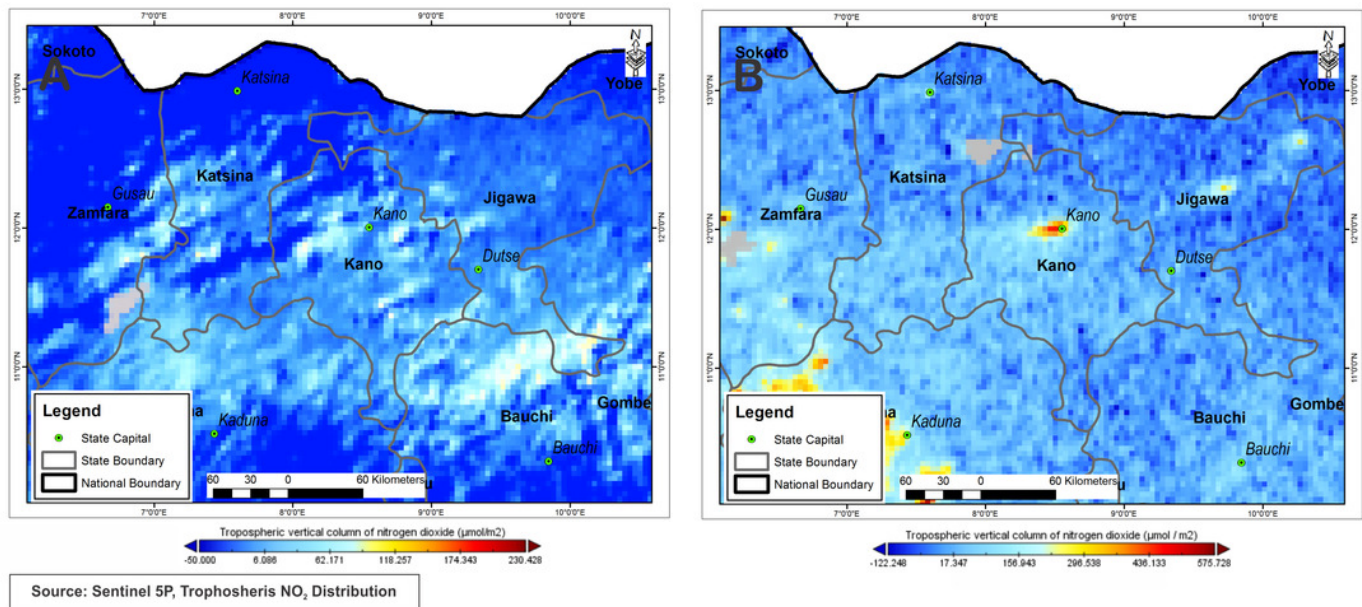



Figure 7

Nitrogen dioxide concentration levels over Abuja during lockdown period April, 10-18, 2020 (A) and pre-lockdown period Dec., 10-14, 2019 (B).

Figure 8

Nitrogen dioxide concentration levels over Owerri and Onitsha during lockdown period April, 10-18, 2020 (A) and pre-lockdown period Dec., 10-14, 2019 (B).