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VARIATIONS IN NO_2 CONCENTRATIONS BEFORE, DURING, AND AFTER THE COVID-19 LOCKDOWN IN THE WILAYA OF ALGIERS

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ABSTRACT

Unplanned urbanization and industrialization are among the leading causes of air pollution in urban environments, with significant economic, social, and environmental consequences, posing threats to human health. Atmospheric pollution has been the subject of multiple studies worldwide, especially in developed countries. However, developing countries, including Algeria, face difficulties in taking appropriate measures to preserve air quality due to the lack of sufficient monitoring data. To address this problem, satellite remote sensing technology has been used to monitor the spatio-temporal evolution of pollutant emissions. This study focused on identifying high-pollution areas in the wilaya (province) of Algiers, characterized by intense urbanization and increasing economic and industrial activities. The impact of reductions in anthropogenic emissions during the Covid-19 pandemic lockdown on air quality was also examined. For this purpose, variations in NO2 concentrations in Algiers before, during, and after the lockdown were analyzed using Google Earth Engine (GEE) and data from the TROPOMI tropospheric monitoring instrument. The study focused on 11 selected sites across the wilaya, revealing that the highest NO2 concentrations were observed in densely populated and industrial areas such as Oued Smar, El Harrach, and Baraki, where heavy traffic combines with significant industrial activity. Reductions in NO2 levels were observed across the wilaya during the lockdown, attributed to the considerable decrease in mobility and industrial activities during the Covid-19 pandemic.

KEYWORDS

Urban, Atmospheric Pollution, NO_2, Remote Sensing, Covid-19, Algiers

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Introduction

Environmental monitoring has become an essential requirement for any urban study. The strong demographic growth and accelerated, unplanned urban expansion have inevitably impacted the environment (Messaadi, 2021). Indeed, urban growth involves annexing new territories within the city's spatial perimeter. The peri-urban zone thus shifts and moves increasingly farther away, leading to increased mobility flows, which inevitably creates problems. In urban areas, pollution mainly originates from three sources (Glandus, L. M., & Beltrando, G., 2013): industrial activities, domestic sector activities, and road traffic, now considered the most significant source of emissions within urban agglomerations (CITEPA, 2011). This rapid urbanization, accompanied by increased consumption of water and energy, ever-growing waste production, and especially a rise in automobile traffic, has led to a severe deterioration of the atmosphere (Tella, A., & Balogun, A.L., 2022), thus affecting human health and the environment (Tella, A., & Balogun, A.-L., 2021).

In this context, large cities fear being suffocated by automobiles (Bourboulon, I., 1997), which in turn contributes to high levels of air pollution and greenhouse gas emissions. This atmospheric pollution has harmful consequences on human health, particularly for vulnerable or sensitive individuals (CITEPA, 2023), leading to increased hospitalizations and premature deaths (Mabahwi, N. A., et al., 2015). However, air pollution is not only the cause of health problems; it also has detrimental effects on ecosystems, resulting in negative health and economic consequences for society.

Urban Atmospheric Pollution

According to Wiwanitkit (2011), pollution is the unwanted destruction of the natural environment by natural aggressions and human activities. Air pollution refers to a mixture of gases and suspended particles present in the air (Ahluwalia, V. K., & Malhotra, S., 2008)—both indoor and outdoor—whose concentration levels vary depending on emissions and weather conditions. Urban atmospheric pollution is caused by the local environment's inability to absorb the level of waste produced by a large number of people concentrated in relatively small areas (Kemp, D. D., 2004).

The main pollutants likely to cause significant damage to health, the environment, and property (Mabahwi, N. A., et al., 2015; Wang, S., et al., 2022) include sulfur dioxide (SO_2), produced from the combustion of fossil fuels such as coal, diesel, oil, etc., or emitted by certain industrial processes. nitrogen dioxide (NO_2), also produced by combustion processes, notably from vehicles, power plants, and factories ; and carbon monoxide (CO), resulting from the incomplete combustion of organic matter such as fossil fuels, coal, and waste. The primary sources of CO emissions are motor vehicles, industrial equipment, and domestic households. Additionally, tropospheric ozone (O_3), a secondary pollutant, results from complex chemical reactions between certain pollutants (He et al., 2017; Xu & Lin, 2017). Fine particulate matter with an aerodynamic diameter of less than 2.5 microns ($PM_{2.5}$) is also considered a reference pollutant (Mabahwi, N. A., et al., 2015).

Although these atmospheric pollutants are mainly associated with human activity, natural processes such as forest fires, volcanic eruptions, etc., also play a role.

Each pollutant has different health effects. When NO_2 is inhaled by humans, it penetrates the bronchi and can cause asthma attacks or lung infections. Similarly, SO_2 can irritate the mucous membranes of the eyes, nose, throat, and respiratory tract. In contrast, CO causes respiratory disorders, worsens cardiovascular diseases, and can be fatal in high doses. Ozone (O_3), due to its oxidizing nature, can cause eye irritation, respiratory difficulties, or pulmonary diseases like asthma. Asthmatic individuals, young children, and pregnant women are the most vulnerable to these pollutants. Thus, air pollution is a major public health problem worldwide. According to a World Health Organization report (WHO, 2016), air pollution causes the deaths of 7 million people globally each year.

In the terrestrial environment, atmospheric pollution causes significant short-, medium-, and long-term damage, including the destruction of vegetation, soil acidification, and the deterioration of buildings and historical monuments.

Study Area

The World Health Organization conducts epidemiological studies aimed at establishing limit values for certain air pollutants based on their effects on human health. Unfortunately, these limit values are often not respected in several countries, including Algeria, where air quality monitoring is insufficient.

Indeed, like many developing countries, Algeria lags in preserving air quality due to the absence of sufficient monitoring data. The country has only a few air quality monitoring stations, with just four industrial cities (Algiers, Oran, Skikda, and Annaba) equipped with monitoring networks. These networks are often non-operational (Terrouche, A., & Ali-Khodja, H., 2016; Belhout, D., 2019), meaning that virtually the entire country is unmonitored. To ensure adequate intervention by agencies responsible for air quality, it is necessary to create maps showing the spatial distribution of pollutants across a region. This requires dense spatiotemporal observations, which is challenging due to the high cost of measurement stations. Therefore, we opted for satellite remote sensing technology, which allows us to monitor the evolution of pollutant emissions over time, especially in regions poorly covered by ground observation systems.

In this study, our objective was to identify high-pollution areas in the wilaya of Algiers that require increased monitoring. Examining the impact of the Covid-19 pandemic lockdown on air quality is also an interesting question. The results of this study can help policymakers identify necessary measures to reduce atmospheric pollution in the region.

We chose the region of Algiers as our study area due to its high urban concentration and intense residential and economic activities linked to industry. Additionally, the vehicle fleet in the region has increased considerably, reaching 1,689,242 vehicles by the end of 2018, representing over 26% of the country's vehicle fleet, according to the National Statistics Office (ONS, 2018). Roadways are often congested due to the large number of vehicles, reducing traffic speed and worsening greenhouse gas emissions.

The city of Algiers, home to nearly 4 million inhabitants (ONS, 2017), is considered the country's main political, economic, cultural, and demographic hub. Based on population density criteria, the wilaya of Algiers can be divided into four zones : the hyper city center, the city center, and the first and second rings. The hyper city center of Algiers has a very high population density of 33,695 inhabitants per square kilometer. The city center has a slightly lower density of 15,924 inhabitants per square kilometer. The first and second rings have population densities of 7,235 and 2,587 inhabitants per square kilometer, respectively (Safar Zitoun & Tabti-Talamali, 2009).

Methodology

Remote sensing technology offers a considerable advantage over traditional on-site measurements, as it allows coverage of a large geographical area, providing precise information (Ghasempour, F., et al., 2021) on the spatial distribution of a pollutant without the need for numerous ground measurement stations.

The Copernicus Sentinel-5P mission was created to address current environmental concerns as part of a global strategy to mitigate risks related to air pollution. By regularly monitoring the atmosphere with high spatiotemporal resolution, this mission provides valuable data. The TROPOspheric Monitoring Instrument (TROPOMI) was designed to monitor air quality by measuring concentrations of key atmospheric pollutants such as SO_2, NO_2, CO, O_3, HCHO, etc. (El Khoury et al., 2019). TROPOMI offers a significantly improved spatial resolution compared to its predecessors: SCIAMACHY (200 km x 30 km), GOME-2 (80 km x 40 km), and OMI (24 km x 13 km). These products feature a swath width of 2,600 km and a spatial resolution of 7 km x 3.5 km (3.5 km x 3.5 km after August 6, 2019), allowing for city-scale air pollution resolution.

The study selected SO_2, NO_2, CO, and O_3 as pollution indicators. However, data related to SO_2 and O_3 are incomplete, while CO data show no change throughout the study period. Consequently, the only pollutant analyzed was NO_2. The TROPOMI NO_2 processing uses algorithms developed for the DOMINO-2 product and the reprocessed EU QA4ECV NO_2 dataset for OMI, adapted for use with TROPOMI.

Data analysis was conducted by considering periods before, during, and after the Covid-19 pandemic lockdown. This approach allows for a better understanding of the impact of anthropogenic pollutants on air quality. In February 2020, the World Health Organization (WHO) declared that the COVID-19 outbreak, which began in China in December 2019, had become a global pandemic (WHO, 2020). Following this declaration, immediate measures were taken by Algeria to reduce the virus's spread. The mandatory quarantine ordered by the government had a significant impact on automobile mobility in most Algerian cities, as in many cities worldwide (Parr et al., 2020). Additionally, reductions in economic and industrial activities associated with the pandemic were reported.

On March 10, 2020, the Minister of Health announced the President of the Republic's instructions banning sports, cultural, and political gatherings; various sports activities were also decided to be held without spectators. On March 12, 2020, the closure of all educational institutions—from primary schools to universities and vocational training centers—was ordered. On March 17, 2020, the Ministry of Religious Affairs and Wakfs ordered the closure of all mosques and places of worship in Algeria. On March 19, 2020, all public and private public transport within cities and between wilayas, as well as rail traffic, were suspended. On March 23, 2020, a partial lockdown from 7 p.m. to 7 a.m. was imposed in the wilaya of Algiers, with a ban on gatherings of more than two people and the closure of party halls, celebrations, family festivities, cafes, restaurants, and shops. On April 23, 2020, a relaxation of the lockdown was decided in the wilaya of Algiers.

Consequently, the dates selected for this study are during the pandemic, specifically from March 23, 2020 (start date of the lockdown in the wilaya of Algiers), to April 23, 2020 (date of lockdown relaxation). Pollutant concentrations during this period were compared to those before and after the lockdown, i.e., 2019 and 2021, respectively.

To deepen the study, 11 sites were selected evenly across the study area. These sites are located in highly urbanized areas with high population density. The presence of industrial zones in their vicinity was also a selection criterion. Pollution data corresponding to each selected site were subjected to statistical analysis using the Wilcoxon test. This non-parametric statistical test allows for comparing differences between two paired data groups. Its objective is to determine whether there is a significant change between the different periods studied.

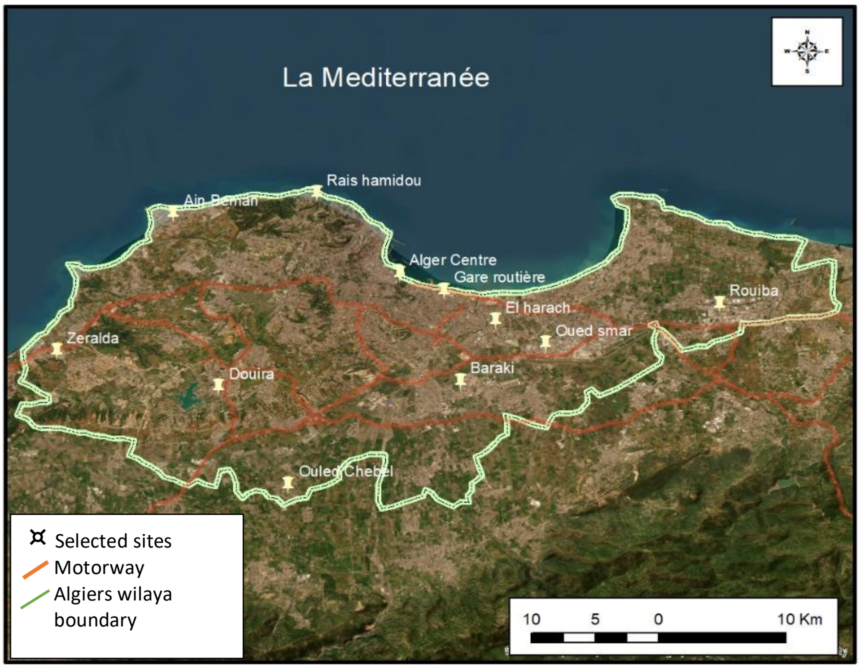

Fig. 01: Study area showing the selected sites

Results and Discussions

The distribution of NO2 concentrations in the study area varies from one location to another, as shown by the images presented in Figure 1. This variation is likely due to spatial disparities in the intensity of emissions from human activities, such as road traffic, industry, and other emission sources. The spatial distribution of NO2 concentrations shows a noticeable increase in the central and southeastern regions, compared to the western regions. It is observed that the highest NO2 concentrations are found in densely populated areas with heavy road traffic. Significant concentrations are also present around industrial zones, such as the Oued Smar and Rouiba regions, where heavy traffic combines with intense industrial activity. High levels of NO2 pollution are also observed in the Baraki area, which houses the refinery.

These concentrations decreased in 2020 (during the lockdown period) compared to 2019, both in urban areas and near industrial zones. This reduction is linked to Covid-19 pandemic management measures, which significantly limited mobility and economic activity. However, high levels were noticed in the southern part (Ouled Chbel region). NO2 concentrations further increased in 2021, but in a much more pronounced manner. The results thus indicate that NO2 is primarily emitted by road traffic and industrial activities.

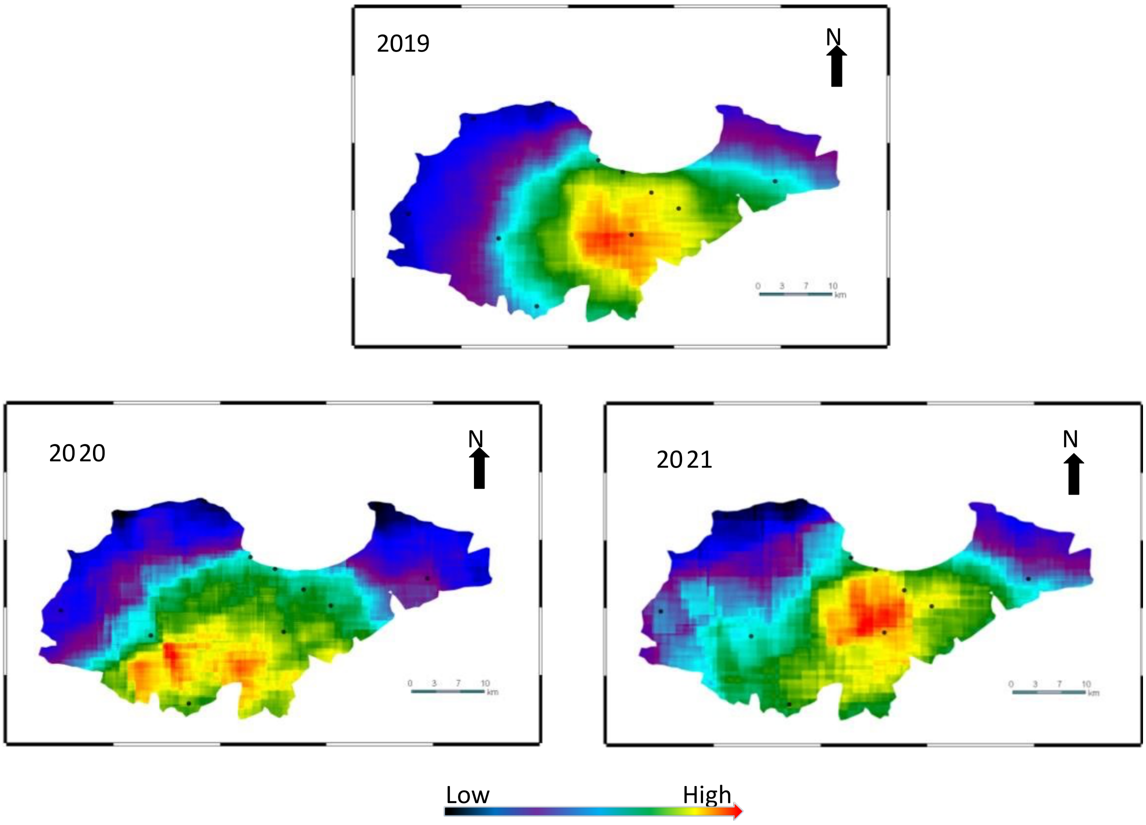

Fig. 02: Maps of the Average Concentrations of Nitrogen Dioxide (NO_2) from March 23 to April 23 in the Years 2019, 2020, and 2021

The curves presented in Figure 2 illustrate the variations in average NO2 concentrations across the 11 selected sites between the years 2019, 2020, and 2021 (from March 23 to April 23). The Oued Smar (0.218 mmol/m²), El Harach (0.213 mmol/m²), and Baraki (0.231 mmol/m²) sites recorded the highest concentrations during the studied periods. However, all selected sites experienced a significant decrease in NO2 concentrations during the lockdown period compared to those observed in 2019 and 2021.

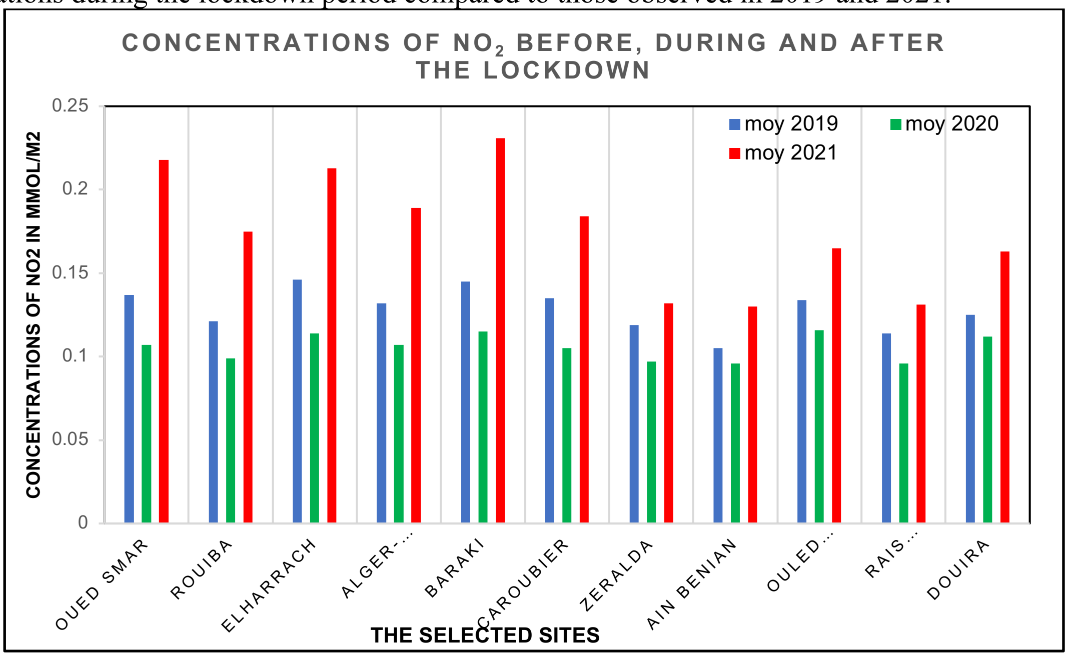

Fig. 03: A Comparison of the Average Concentration of Nitrogen Dioxide (NO_2) in the Years 2019, 2020, and 2021 for the Various Selected Sites.

According to the results of the non-parametric Wilcoxon test presented in the table below, a significant reduction in NO2 concentrations was observed in industrial areas and high-density population zones, specifically in Oued Smar, Rouiba, El Harrach, Alger Centre, Baraki, and Caroubier, between 2019 and 2020 (ρ (2019-2020) < 0.05). It is noteworthy that these areas were the most affected by the Covid-19 lockdown measures. However, in 2021, with the lifting of the lockdown and the resumption of economic activities, a significant increase in NO2 emissions was observed, resulting in statistically significant changes compared to 2020. Among the 11 selected sites, Oued Smar and Baraki recorded the most substantial changes (over 50%) between 2020 and 2021.

Table No. 01 : The Average Concentrations of Nitrogen Dioxide (NO_2) (mmol/m²), the Percentage of Temporal Change Rates, and the Results of the Non-Parametric Wilcoxon Test for the Various Periods. (The values in red are higher than the critical values of the Wilcoxon test, meaning that the corresponding changes are not statistically significant.)

Zone	Average 2019	Average 2020	Average 2021	Rate (19-20)%	Rate (20-21)%	ρ (19_20)	ρ (20_21)
Oued smar	0,137	0,107	0,218	21,90	-50,92	122	53
Rouiba	0,121	0,099	0,175	18,18	-43,43	125	92
ElHarrach	0,146	0,114	0,213	21,92	-46,48	125	67
Alger-centre	0,132	0,107	0,189	18,94	-43,39	126	85
Baraki	0,145	0,115	0,231	20,69	-50,22	125	59
Caroubier	0,135	0,105	0,184	22,22	-42,93	97	75
Zeralda	0,119	0,097	0,132	18,49	-26,52	170	114
ain benian	0,105	0,096	0,13	8,57	-26,15	150	96
ouled chbel	0,134	0,116	0,165	13,43	-29,70	154	111
Rais hamidou	0,114	0,096	0,131	15,79	-26,72	132	136
Douira	0,125	0,112	0,163	10,40	-31,29	172	128

In conclusion, the study results confirm that NO2 emissions are primarily due to road traffic and industrial activity. This finding is consistent with the 1995 report from the Ministry of Land Use Planning and Environment (MATE), which estimated that road traffic was responsible for a significant contribution to NO2 emissions (69%), while the industrial sector accounted for 29% of NO2 emissions. Another study conducted in 2019 by Belhout Dalila also confirmed that nearly 82% of total NO2 emissions in the Wilaya of Algiers originated from road traffic.

Several studies worldwide have also used satellite observation data, particularly from TROPOMI, to assess variations in atmospheric pollutant concentrations, including NO2. The results show that NO2 concentrations decreased in urban and industrial areas in 2020 compared to the same period in 2019 (Ali et al., 2021; Wang, S et al., 2022; Ghasempour, F et al., 2021). Overall, satellite data provided significant results for assessing air quality over time and space, especially during the Covid-19 lockdown.

Conclusions

In this study, the spatio-temporal pattern of the NO2 atmospheric pollutant, derived from TROPOMI Sentinel-5P, was monitored and studied before, during, and after the lockdown in the Wilaya of Algiers. The GEE platform was used for acquiring and processing satellite imagery and data analysis.

The results, as shown by the images, demonstrate that the highest NO2 concentrations are located in the vast southeastern area of Algiers, encompassing the industrial zones of Oued-Smar and Rouiba, as well as the Baraki refinery. These concentrations are also high near the city center, characterized by high population density and significant road traffic. The analysis of average NO2 concentrations at the 11 selected sites across the Wilaya shows that these concentrations were significantly lower during the 2020 lockdown compared to the same period in 2019. After the lockdown, concentrations increased and even surpassed 2019 levels. Overall, a statistically significant decrease in NO2 concentrations was observed in most areas during the Covid-19 lockdown.

In summary, the study's results confirm that NO2 concentrations are primarily influenced by road traffic and industrial activities. Future studies analyzing different atmospheric pollutants over a larger area will be necessary.

REFERENCES

1. Ahluwalia, V. K., & Malhotra, S. (2008). Environmental Science. Delhi, India: Ane Books India
2. Belhout, D. (2019). « Evaluation des émissions atmosphériques et modélisation de la qualité de l'air dans le grand Alger : scénarios à l'horizon 2030 (Doctoral dissertation)
3. Bourboulon, I. (1997). « Des villes asphyxiées par l'automobile. » Le monde Diplomatique, Décembre, p.18
4. CITEPA, 2011. *Emissions dans l'air en France métropolitaine*, http://www.citepa.org.
5. CITEPA, 2023. *Résumé de la qualité de l'air dans le monde*, http://www.citepa.org.
6. El Khoury, E., Ibrahim, E., & Ghanimeh, S. (2019). « A look at the relationship between tropospheric nitrogen dioxide and aerosol optical thickness over lebanon using spaceborne data of the copernicus programme ». In *2019 Fourth International Conference on Advances in Computational Tools for Engineering Applications (ACTEA)* (pp. 1-6). IEEE.
7. He, W., Wang, Y., Zuo, J., & Luo, Y. (2017). « Sectoral linkage analysis of three main air pollutants in China's industry: comparing 2010 with 2002. » *Journal of Environmental Management*, *202*, 232-241.
8. Ghasempour, F., Sekertekin, A., & Kutoglu, S. H. (2021). « Google Earth Engine based spatio-temporal analysis of air pollutants before and during the first wave COVID-19 outbreak over Turkey via remote sensing. » *Journal of Cleaner Production*, *319*, 128599.
9. Glandus, L. M., & Beltrando, G. (2013). « Les déplacements urbains et la pollution de l'air dans des villes intermédiaires : enjeux politiques et environnementaux. » *Norois. Environnement, aménagement, société*, (226), 25-40.
10. Kemp, D. D. (2004). « Exploring environmental issues : An integrated approach. » London, United Kingdom: Routledge
11. Mabahwi, N. A., Leh, O. L. H., & Omar, D. (2015). « Urban air quality and human health effects in Selangor, Malaysia ». Procedia-Social and Behavioral Sciences, 170, 282-291.
12. Messaadi, I., & Raham, D. (2021). « étude méthodologique de la croissance urbaine en Algérie « (Doctoral dissertation, Université Frères Mentouri-Constantine 1).
13. ONS (Office National des Statistiques) (2016). Alger. http://www.ons.dz
14. ONS (Office National des Statistiques) (2017)
15. ONS (Office National des Statistiques) (2018)
16. OMS (Organisation mondiale de la santé) (2020). Allocution liminaire du Directeur général de l'OMS lors du point presse sur la COVID-19 - 11 mars 2020.
17. Parr,S., Wolshon, B., Renne, J., Murray-Tuite, P., Kim, K. (2020). « Impacts de la pandémie de COVID-19 sur la circulation: analyse à l'échelle de l'État de la séparation sociale et de la restriction d'activité », Nat. Hazards Rev., 21 (3).
18. Tella, A., & Balogun, A. L. (2022). « GIS-based air quality modelling: Spatial prediction of PM10 for Selangor State, Malaysia using machine learning algorithms. » Environmental Science and Pollution Research, 1-17.
19. Tella, A., & Balogun, A. L. (2021). « Prediction of ambient PM10 concentration in Malaysian cities using geostatistical analyses. » Journal of Advanced Geospatial Science & Technology, 1(1), 115-127.
20. Terrouche, A., & Ali-Khodja, H. (2016). « Caractérisation de la pollution de l'air par les particules et les éléments métalliques dans la ville de Constantine. » (Doctoral dissertation, Université Frères Mentouri-Constantine 1).
21. Wang, S., Chu, H., Gong, C., Wang, P., Wu, F., & Zhao, C. (2022). « The Effects of COVID-19 Lockdown on Air Pollutant Concentrations across China: A Google Earth Engine-Based Analysis. » International Journal of Environmental Research and Public Health, 19(24), 17056.
22. Xu, R., & Lin, B. (2017). « Why are there large regional differences in CO2 emissions? Evidence from China's manufacturing industry. » Journal of Cleaner Production, 140, 1330-1343.
23. Zitoun, M. S., & Tabali-Talamali, A. (2009). « La Mobilite Urbaine Dans L'agglomeratin D'alger: Evolutions Et Perspectives. ».