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Additional Information

Analysis of the effect of COVID-19 on air pollution: Perspective of the Spanish case

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Abstract: The pandemic caused by coronavirus COVID-19 is having a worldwide impact that affects health, the economy, and indirectly affects air pollution in cities. In Spain, the effect has evolved from being anecdotal in January 2020 to become the second country in Europe with the highest number of cases (614.000 cases by 17/09/2020), which has affected the health system and caused major mobility restrictions. In contrast, COVID-19 has affected air pollution and energy consumption in the country. This article analyzes the indirect effect produced by this pandemic on air pollution, referenced to various stages that occurred in Spain. First stage: without public awareness of COVID-19 impact (mid-January 2020); second is when Spanish Government alerted (late February 2020), third, after the decree of alarm and mobility restriction of citizens by the government (March 2020) along with the various phases of the de-escalation. The indirect effect produced by this pandemic on air pollution in Spanish cities has been resulted in a decrement of 70% to 80% of average, taking into account dates after the decree of alarm and mobility restriction by the Spanish government (14/03/2020), compared to days prior to that date. Thus, the results of this analysis indicate a significant alteration in air pollutants, this alteration patterns have followed similar paths over different countries worldwide improving the air quality (Dutheil et al., 2020).

Keywords: Air pollution; COVID-19; air quality, Cities; Energy

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1. Introduction

The covid-19 outbreak has impacted worldwide which led to the stoppage of economic activities and the drop of stock markets. In order to prevent the transmission of the virus also known as SARS-CoV-2 (COVID 19) precautionary measures have been taken such as masks, gloves on daily basis along with mobility restrictions in case of the increasing tendency of the covid-19 infections. Undoubtedly, the negative effect of coronavirus is led by more than 926,544 deceased people (WHO 2020) and 29 million cases worldwide detected on 17th September of 2020 and the number continues to grow in countries such as India, Brazil, and the USA. The distribution of the affected countries is shown in figure 1, which originated in China, and the affected countries detected on September 17th, 2020 (Web 1 2020).

On the other hand, various environmental aspects have been influenced by the pandemic. Factors such as a drastic closing of economic activity, industry, and transport have affected the environment indirectly reducing the number of air pollutants such as PM_{10} and NO_2. Satellite images show the reduction of CO_2 up to 25% in China due to the coronavirus crisis (approximately 200 million tons) (EPA 2020). After the pandemic impact on Italy, satellite images were taken by the European Space Agency (ESA) also show the decrease of pollutant concentration, such as nitrogen dioxide CO_2 (ESA 2020) (a toxic compound that negatively affects the air quality, in addition to being a greenhouse gas) in the country. A reduction of air pollutants is common during times of crisis (Web 2 2020). This is due to less mobility of people and transportation among with the reduction of economic activities that depend on fossil fuel, responsible for CO_2 emission. This gas is one of the main greenhouse gases, while NO_2 is a highly toxic gas associated with vehicles that run on diesel. Although initially, these measures have created positive impacts on the environment, researchers fear that the situation will turn back once the pandemic is overcome. The International Energy Agency (IEA) can pose a threat to climate action in the long-term, by reducing the investment in clean energy (IEA 2020). It should be taken into account that with the revitalization of the economy, pollution levels will rise again. However, this situation can be controlled by taking necessary measures to reduce greenhouse gas emissions. On the other hand, it is worth mentioning the tendency of air quality within international cities analyzed over a similar period of time as it is in this paper. Regarding the Asian continent, the values of air pollutants are presented at higher rates as the most polluted cities are located in this continent (Rodríguez and Rodríguez 2020) Despite having a higher pollution rate, it is noticeable the decreasing in air pollutants and their emissions once the outbreak of COVID-19 started (Rojas et al., 2021) and how it has been linked to the disease since the outbreak.

The current situation of COVID-19 cases is shown in figure 1 (Web 1).

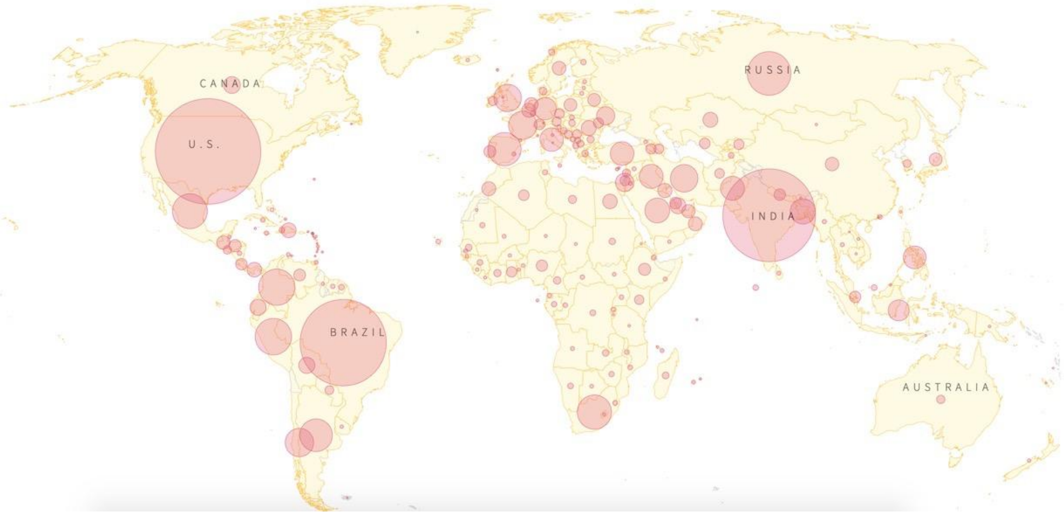


Figure 1. Countries with reported confirmed cases of COVID-19, September 17th, 2020. Source: Reuters.

In the case of Spain, the COVID-19 infections increased exponentially due to the lack of awareness by the Spanish citizens which led to a total amount of 1.160.083 cases reported on the 29th of October 2020. It is remarkable the other causes of deceases in Spain; 10.000 annual deaths are caused by air pollution, a number much higher than the mortality associated with traffic accidents, which is 1,700 deaths per year, according to the Spanish Society of Pneumology and Thoracic Surgery (SEPAR 2020). Moreover, among the causes of death, tobacco is the third cause of death in the world, while air pollution is the fourth, with 7 million deaths worldwide, according to the World Health Organization (WHO 2020). The most harmful environmental pollutants are nitrogen oxide (NO_2), which causes the most deaths in Spain (around 6,000 a year), followed by suspended particles (2,600 annual deaths) and tropospheric ozone (more than 500), and others like sulfur dioxide, carbon monoxide or lead (WHO 2020).

The global cost of fossil fuel has been quantified by different studies, showing an estimated cost of 8,000 million dollars every day, around 3.3% of world GDP or 1.5 times the GDP of Spain (Farrow, Miller and Myllyvirta 2020).

Therefore, this article tackles the indirect effect produced by this pandemic on air pollution in reference to various stages that occurred in Spain. Five cities have been chosen in order to analyze the evolution of air pollution, cities such as Valencia, Madrid, Barcelona, Sevilla, and Bilbao. These cities are of high interest due to their large urban and high-traffic areas, where the rolled traffic on a daily basis is higher than other Spanish cities. The study for these cities has been conducted first, when there was no public awareness of the COVID-19 impact (mid-January 2020); second, when Spanish Government alerted (late February 2020), third, after the decree of alarm and mobility restriction of the citizens by the government (March 14th, 2020), along with the different phases of the de-escalation. The state of alarm decreed by the Spanish government from March 14th, imposes the confinement of citizens, the reduction of the circulation of private vehicles, reduction of buses, taxis, and railways services, and partial closure of Spanish airspace. These restrictions occurred at the same time in all Spanish cities.

2. Materials and Methods

In order to analyze the effects of the pandemic caused by the COVID-19 virus on air pollution in Spain, the following resources and sources have been taken into considered:

- The European Space Agency (ESA) and NASA pollution monitoring satellites (ESA, 2020; NASA 2020). These satellites allow visualizing some side effects of the pandemic associated with air pollution of different regions. Sentinel-5P is the first Copernicus mission satellite devoted to monitoring our atmosphere. It has a Tropomi instrument that is capable of mapping numerous trace gases, such as, nitrogen dioxide, ozone, formaldehyde, sulfur dioxide, methane, carbon monoxide, and aerosols, which affect the breathable air and, therefore, our health and environment. These satellite images will provide information on atmospheric quality, stratospheric ozone, and solar radiation, in addition to monitoring the weather.
- Atmospheric pollutants measurement station of Barcelona, Madrid, Valencia, Sevilla, and Bilbao in Spain along with European stations.
- Atmospheric pollutants measurement stations measure the main pollutant sources present in urban environments such as sulfur (SO_2) and nitrogen oxides (NO, NO_2, NOx), carbon monoxide (CO), Ozone (O_3), and the suspended particles with fractions less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2,5}$), and organic compounds (VOCs, benzene, toluene, xylene). Nitrogen oxides (NO_2) and PM_{10} require special attention. The first of them is originated by the combination of nitrogen and oxygen present in the air as a consequence of combustion processes, including road traffic, while PM_{10} particles are also originated during combustion processes (carbonaceous particles, soot), although they can also have a natural origin (fine sand and other particles) due to the wind. In addition to particle analysis, measurements of meteorological parameters are made to determine the dispersion of pollutants such as temperature, humidity, wind direction, and speed, as well as atmospheric pressure and solar radiation. The normally used model for the weather station is the model called GAIA-A13 (figure 2).

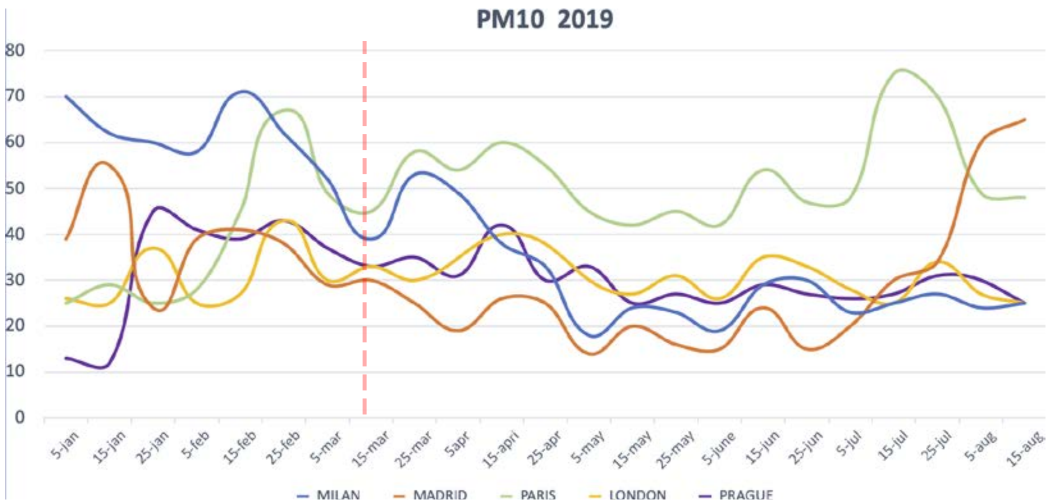
Figure 2. Weather station GAIA A13 Monitoring Station.

The Gaia A13 comes with 2 redundant PM sensors (so 3 in total). This setup is mandatory for “official” AQI readings (e.g., data broadcasted to a wide audience), as a way to ensure the data reliability of the PM sensors. The meteorological sensor is a high precision sensor for Relative Humidity, Temperature, and Pressure sensing.

- Particulate Matter Sensors: 3x PMS 5003
- Meteorological Sensors: BME 280
- Power Supply: 5V (USB compatible)
- Connectivity: WIFI (with external antenna)
- Dimensions: 130 * 80 * 70 mm
- Weight: 380g

3. Analysis of the effect of COVID-19 on air pollution: Perspective of Europe, Spain, and Italy

European Space Agency (ESA) and NASA have detected significant decreases in nitrogen dioxide (NO_2) in Europe through pollution monitoring satellites. There is evidence that the change is related to the economic slowdown as a consequence of the coronavirus outbreak (ESA 2020). It is remarkable how in Europe the effect of air pollutants decreases in large urban areas as a consequence of mobility restriction and the stoppage of economical activity. First in Italy and then in the rest of the major regions in Europe as it is observed in figure 3 showing the drop of PM_{10} in cities such as Milan, Madrid, Paris, London, and Prague. Figure elaborated with data collected from air quality data platforms through measuring stations. (AQICN 2020).



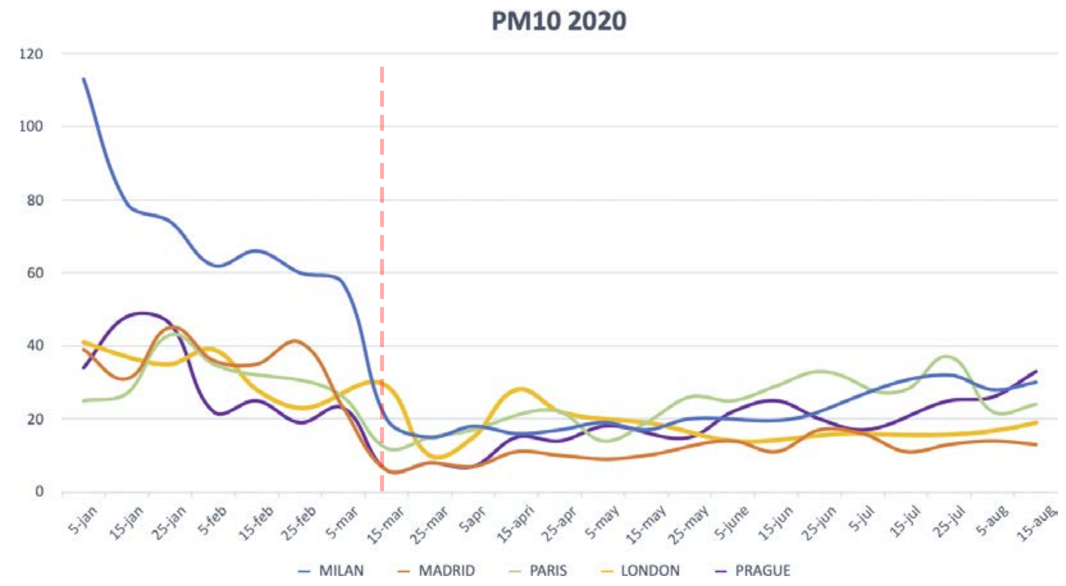


Figure 3. Evolution of PM_{10} from January to August of 2020 and its comparison with 2019.

Figure 4 shows images obtained from the Tropomi instrument, on board the Copernicus Sentinel-5P satellite (ESA 2020), which shows the emissions of nitrogen dioxide (NO_2) and other pollutants from January 1st until March 11th, 2020. Mainly observed the human-caused pollution, due to emissions from tailpipes and the generation of electricity, especially coal-fired power plants. Nitrogen dioxide emissions have been reduced as a consequence of travel restrictions, and many companies or factories closed, using less energy, along with the measures taken by the government of Italy (first) and Spain (later) to prevent the spread of the disease, which have caused a reduction in traffic and industrial activities.

Nitrogen dioxide emissions (NO_2, redder in figure 4 at higher concentration) have been reduced in northern Italy between mid-January to mid-March 2020, in the same way, this reduction can be seen in Spain (ESA 2020). NOx emission from a large area can be subjected to interannual and other systematic variation. Analyzing NOx emission is particularly tricky due to cloud cover, meteorological influences like wind fluctuation, wind speed, etc. (ACP 2020), but as an approximation, it can take a good reference to see the state of the change in air pollution in the observed places.

The reduction of this pollutant, being one of the most harmful substances expelled by vehicles (especially diesel), is seen especially in northern Italy, coinciding with the national lockdown decreed in order to prevent the spread of COVID-19. Along with this positive effect, it must be highlighted the impact of COVID-19 on other fields, such as environmental noise, this factor can present as unwanted issue among citizens living close to locations where industrial activity or traffic activities are presented on high level (Zambrano et al., 2020).Thus with the mobility restrictions, the environmental noise was reduced noticeably during the lockdown period over areas with high ratio of activities such as industrial, commercial or related to vehicles (Díaz et al., 2020).

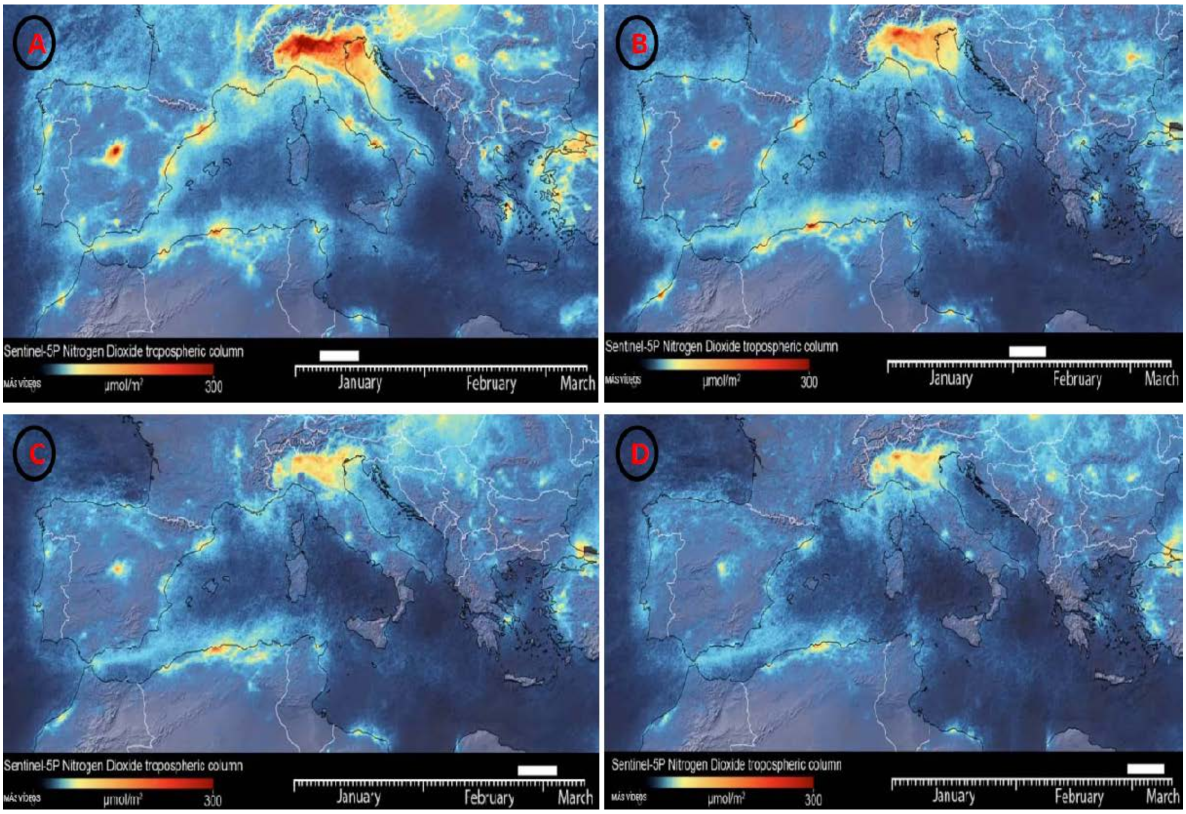


Figure 4. Satellite views of nitrogen dioxide emissions (NO_2, redder on the map at high concentration). Top image (A-early January), bottom image (D-mid-March) (ESA 2020).

In the case of Spain, the NO_2 values can be seen in figure 5 of Spain from January 6th to 20th, 2020 (before quarantine) and from March 23rd to Abril 13th (during quarantine). The data was collected by the Tropospheric Monitoring Instrument (TROPOMI) on the Sentinel-5 satellite of ESA, a related sensor, the Ozone Monitoring Instrument (OMI), and the Aura satellite of NASA, with similar measurements (NASA 2020).

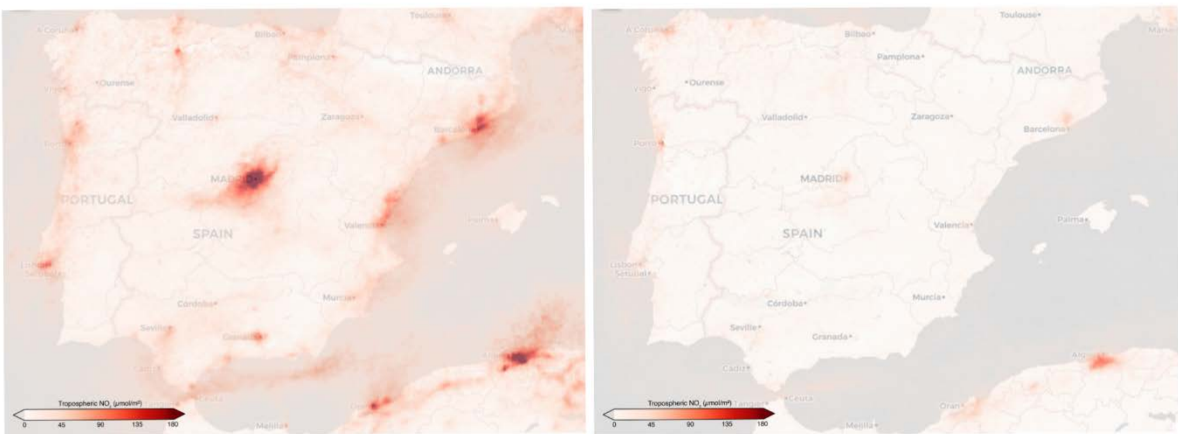


Figure 5. Significant decreases in nitrogen dioxide (NO_2) over Spain. January 6th - April 13th, 2020.

Although Spain's NOX effects and reduction pattern could be very different, observing the change in air pollution produced in other areas due to COVID-19 can serve as a reference for the change that may occur in other countries such as Spain. According to a NASA study, the first evidence of NO_2 reduction was seen near Wuhan, but it eventually spread across the country. Millions of people have been lockdown making it one of the biggest actions in human history (WHO 2020).

In Spain, the electricity demand (REE 2020), by observing the three stages of the crisis, first, when there was no public awareness of the COVID-19 impact (A-mid-January 2020), second, after the first alert by the Spanish Government (B- early March 2020) and third, after the decree of alarm and mobility restriction of the citizens by the government (C-mid-March 2020). Figure 6 then shows the evolution of electricity demand due to the pandemic crisis and actions taken by the Spanish government. Three working days have been taken to show the evolution of electricity consumption (REE 2020). A) Without awareness of the pandemic problem (20/01/2020), with a maximum demand of 39,435 MW. B) After first awareness of the crisis (13/03/2020), with a maximum demand of 33,006 MW. C) After the decree of alarm and mobility restrictions (20/03/2020), with a maximum demand of 30,191 MW. It is observed a reduction in energy consumption up to 25%, compared to January. The decrease in demand must be considered as a foreseen action in the following weeks, given since the last day analyzed was 5 days after the alarm decree, and it is foreseeable that more economic activity will stop. This implies lower pollutant emissions as a consequence of electric power production plants.

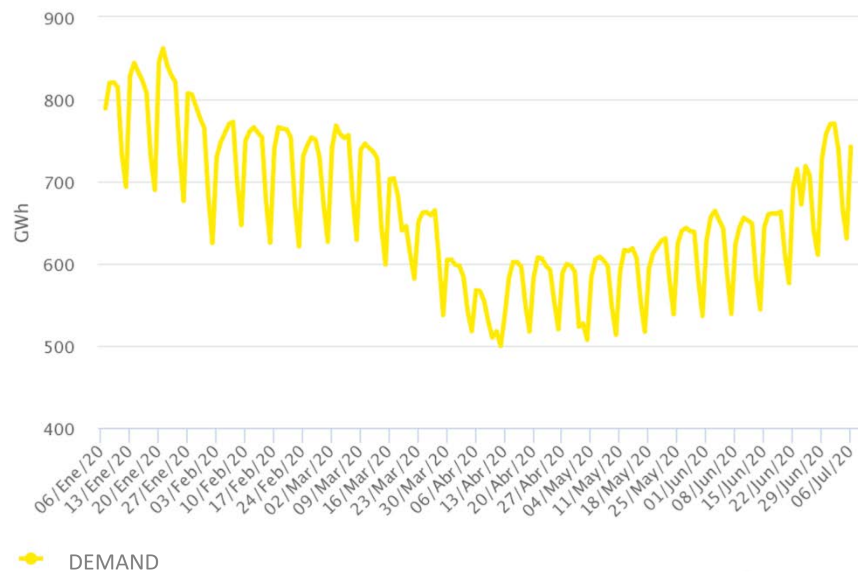


Figure 6. Electricity demand in Spain between January and July of 2020 by the Spanish electric network.

Observing air quality of five Spanish cities (Madrid, Barcelona, Valencia, Sevilla, and Bilbao) through air pollution monitoring stations, it is shown the significant decrease in pollutants, especially NO_2, consequence of the drastic traffic reduction due to mobility restriction ordered by the Spanish government as of March 14th, 2020. The state of alarm and different phases of Spanish countries are shown in table 1:

	STATE OF ALARM	PHASE 0	PHASE 1	PHASE 2	PHASE 3	NEW NORMALITY
VALENCIA	14 March	11 may	18 may	1 June	15 June	21 June
MADRID	14 March	11 may	25 may	10 June	21 June	21 june
BARCELONA	14 March	11 may	25 may	10 June	18 June	19 June
SEVILLA	14 March	4 may	11 may	25 may	10 June	21 June
BILBAO	14 March	4 may	11 may	25 may	10 June	19 June

Table 1. Period and phases of de-escalation of five Spanish cities.

From Figures 7 to 17 it is shown how different cities have been affected by the impact of COVID-19. Starting with Madrid (figure 7 and 8), elaborated with data collected from the F. Ladreda measuring station:

2.1 Analysis of air quality in Madrid

Madrid is among others, the Spanish city with high levels of pollution, due to a large number of traffic movements every day. Figure 7 shows how the city started the year 2020 and 2019 with values around 58 and 49 of PM_{10} and NO_2. Figure elaborated through data extracted from the air quality data platform (AQICN 2020). This tendency continued until the state of alarm (14/03/2020) after this period, a drastic fall can be seen as a result of restriction in mobility ordered by the Spanish Government. The low values continue until phase 0, where some uplifting of restrictions took place, resulting in an increase of pollutants as is shown in figure 7 (ESA 2020). With each phase, the values increase gradually, however, these values are lower than the values before the pandemic or the year 2019.

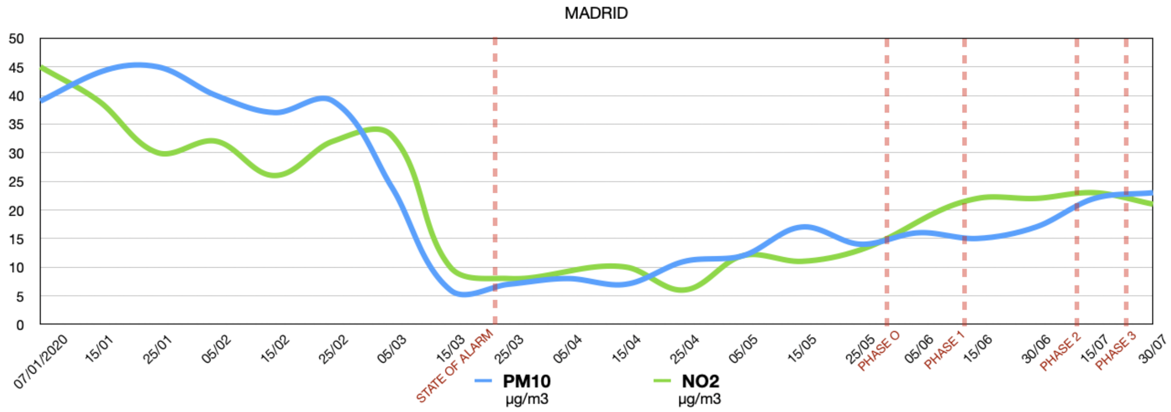


Figure 7. Chart of air pollutants in Madrid (measuring station of F.Ladreda) in five different stages. First without awareness of the pandemic problem (from January to March). After the decree of alarm and mobility restrictions (14/03/2020). And the different phases of de-escalation from phase 0 to Phase 3.

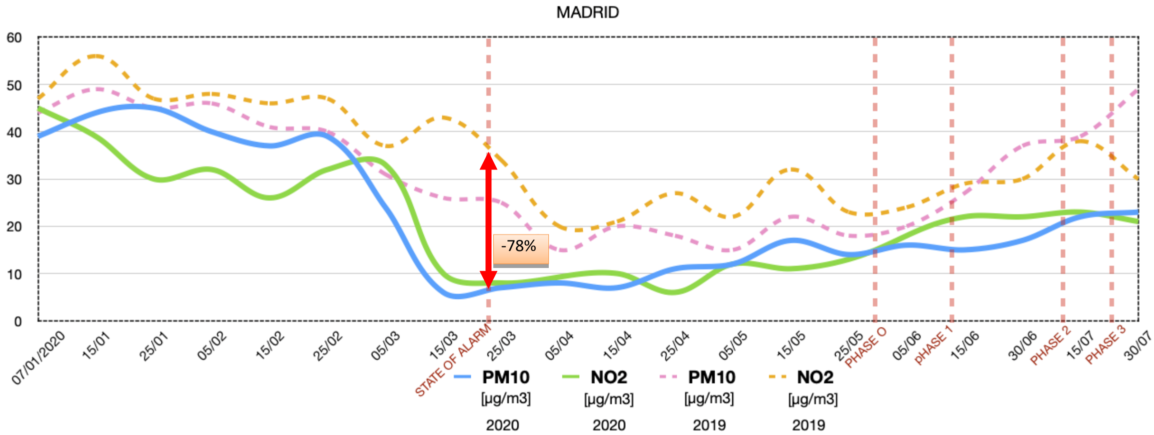


Figure 8. Data comparison of air pollutants in Madrid (measuring station of F. Ladreda) referring to 2020 and its comparison with 2019.

2.2 Analysis of air quality in Barcelona

In the case of Barcelona, observing the air quality data through atmospheric pollution monitoring stations in the city center can be observed as a decrease in pollutants, especially NO2, as a consequence of drastic traffic reduction. NO_2 is originated by the combination of nitrogen and oxygen present in the air as a consequence of combustion processes, including road traffic, while PM_{10} particles are also originated during combustion processes (carbonaceous particles, soot), although they can also have a natural origin (fine sand and other particles) carried by winds.

Barcelona has a high amount of daily traffic which leads to high values of air pollutants in the city, as is shown in Figure 9 and Figure 10 elaborated with the report collected from the air quality data platform (AQICN 2020), which shows the values reaching up to 58 $\mu gr/m^3$ however these values are decreased significantly after the state of alarm on 14/03/2020 The recovery of economic activity lifts the values of air pollutants, yet these values remain lower than the period before COVID-19 or 2019.

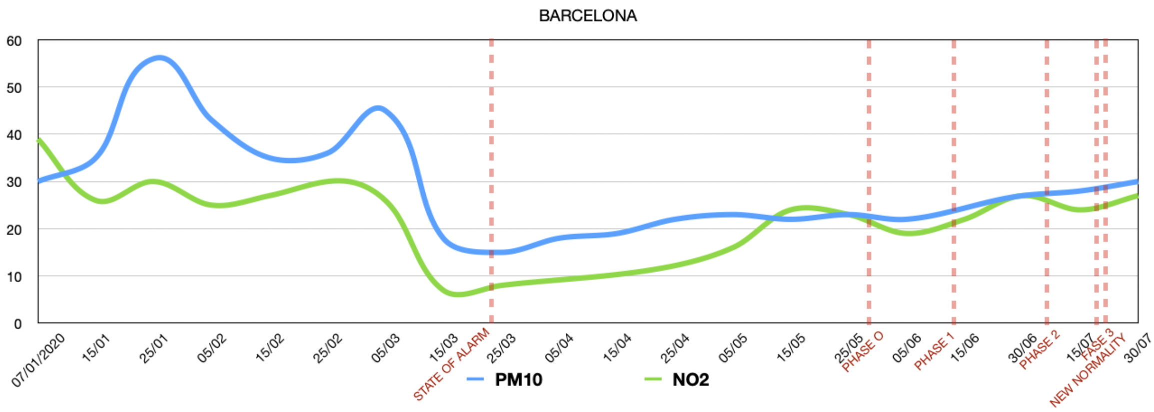


Figure 9. Graph of PM_{10} and NO_2 in Barcelona (measuring station of L'Eixample) in different stages. First without awareness of the pandemic from January to March. After the decree of alarm and mobility restrictions (14/03/2020). And the different phases of de-escalation from phase 0 to new normality.

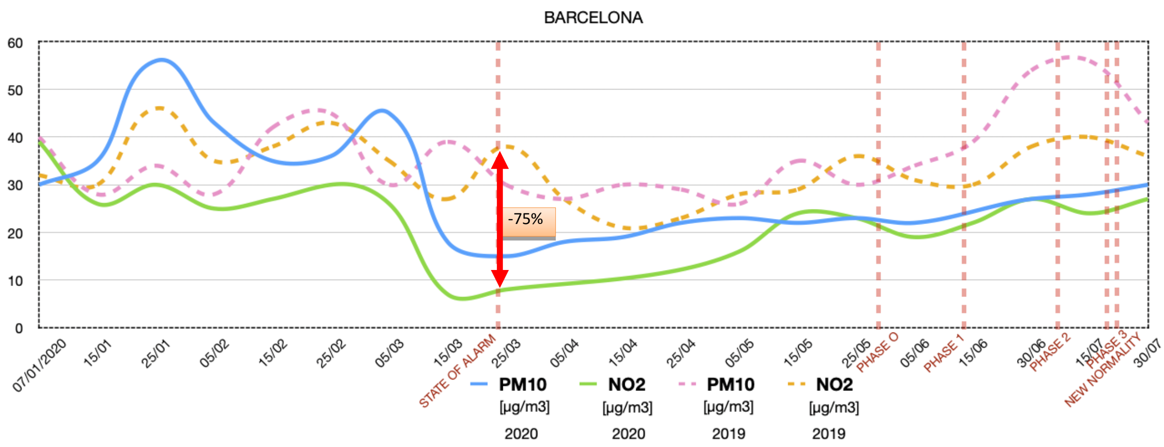


Figure 10. Data comparison of air pollutants in Barcelona (measuring station of L'Eixample) referring to 2020 and its comparison with 2019.

2.3 Analysis of air quality in Valencia

Valencia capital with a total population of 794,288 is another city where traffic is an important source of pollution. The measures of these air pollutants have been done on Pista de Silla, as it is a point of continuous traffic. The values are shown in Figure 11 and Figure 12 indicates the high amount of PM_{10} and NO_2 reaching values around 50 µgr/m^3 according to data extracted from the air quality data platform (AQICN 2020). The tendency of these values experienced a substantial fall after the 14th of March of 2020 as the state of alarm was declared which caused a mobility restriction. In Valencia phase 1 took place on the 11th of May 2020, as it is shown in Figure 11, the air pollutants start increasing until values reach up to 20 µgr/m^3. From phase 1 to new normality the values have been lower than the starting of 2020 or 2019, due to reduced mobility and less industrial activities.

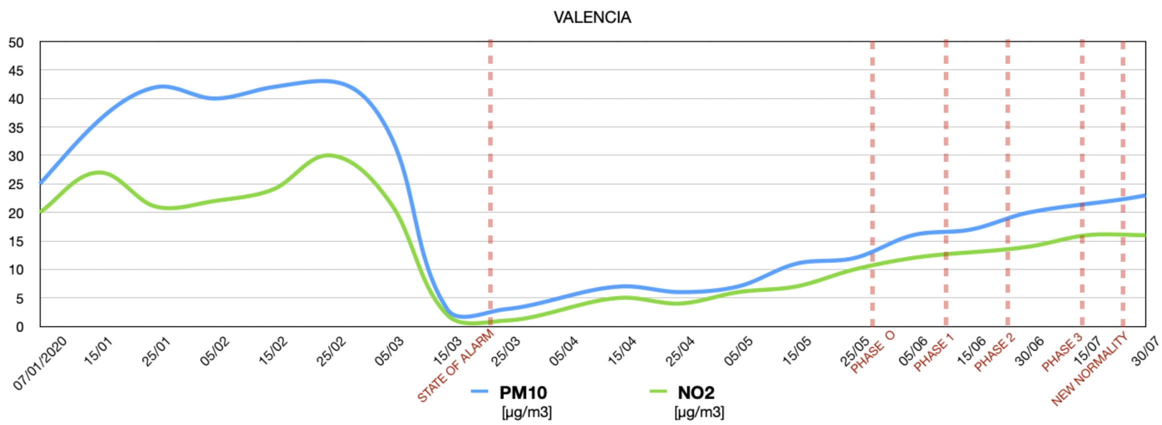


Figure 11. Chart of air pollutants in Valencia (measuring station of Pista de Silla) in five different stages. First without awareness of the pandemic from January to March. After the decree of alarm and mobility restrictions (14/03/2020). And the different phases of de-escalation from phase 0 to new normality.

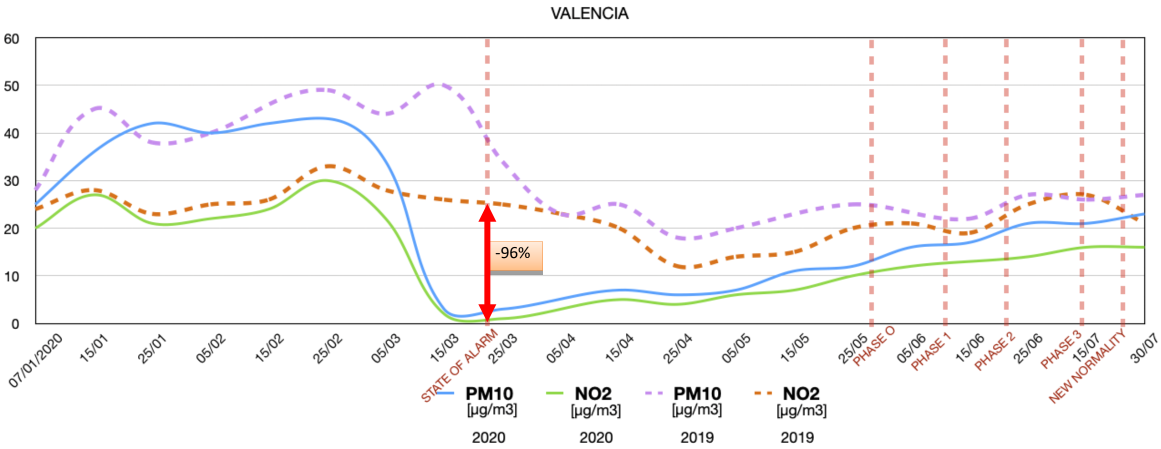


Figure 12. Data comparison of air pollutants in Valencia (measuring station of Pista de Silla) referring to 2020 and its comparison with 2019.

The variation of pollution regarding the current year (2020) and last year (2019) can be seen in figure 13 that analyze the PM_{10} from mid-January to mid-July:

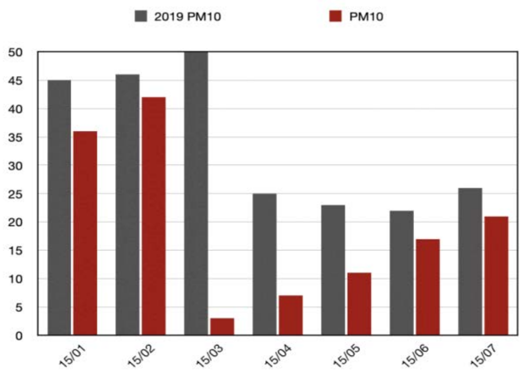


Figure 13. Analysis of PM_{10} in Valencia on Pista de Silla from January 2020 to July 2020 compared with 2019.

2.4 Analysis of air quality in Seville

In the case of Seville, the drop in values is shown in Figure 14, where the airborne pollutants have values of 35 µgr/m3 before pandemic and values up to 50 µgr/m3 in 2019. The figure is elaborated with information extracted from the air quality data platform (AQICN 2020). This indicates how the city faces a serious problem of pollution which has increased in recent years with the massive use of road traffic. The air quality in the city reached critical values in the past years which can be solved by the rethinking of the municipal traffic and infrastructure policies. The values from figure 15 show the tendency of pollutants from January 2020 until July 2020. After the lockdown, the values remained on lower point and with the lifting of lockdown (in Spain executed with various phases) these values increased gradually, however, remaining on lower numbers than last year (2019) in the same period of time. The lockdown lifting plan is described in table 2:

	STATE OF ALARM	PHASE 0	PHASE 1	PHASE 2	PHASE 3	NEW NORMALITY
VALENCIA	*14 March*	*11 may*	*18 may*	*1 June*	*15 June*	*21 June*
MADRID	*14 March*	*11 may*	*25 may*	*10 June*	*21 June*	*21 june*
BARCELONA	*14 March*	*11 may*	*25 may*	*10 June*	*18 June*	*19 June*
SEVILLA	***14 March***	***4 may***	***11 may***	***25 may***	***10 June***	***21 June***
BILBAO	*14 March*	*4 may*	*11 may*	*25 may*	*10 June*	*19 June*

Table 2. Period and phases of de-escalation in Sevilla. Source: own elaboration

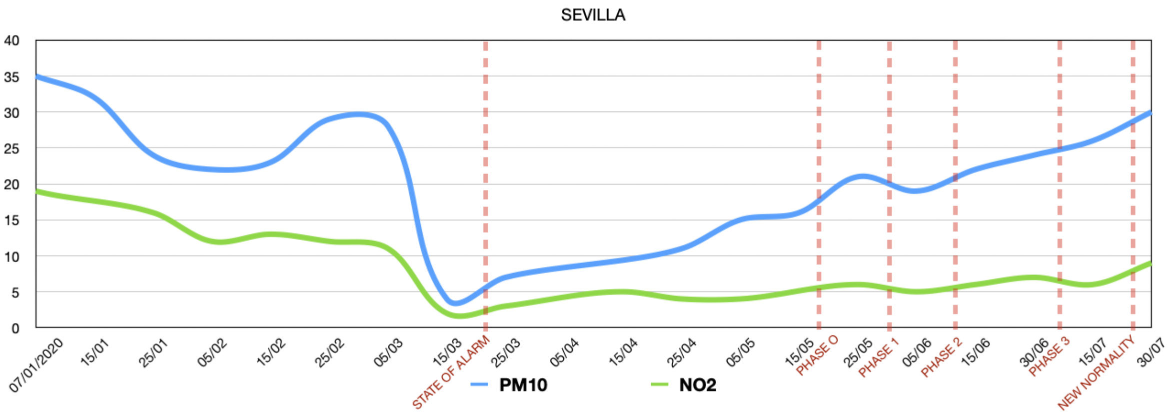


Figure 14. Graph of PM_{10} and NO_2 in Sevilla (measuring station of Santa Clara) in five different stages. First without awareness of the pandemic from January to March. After the decree of alarm and mobility restrictions (14/03/2020). And the different phases of de-escalation from phase 0 to new normality.

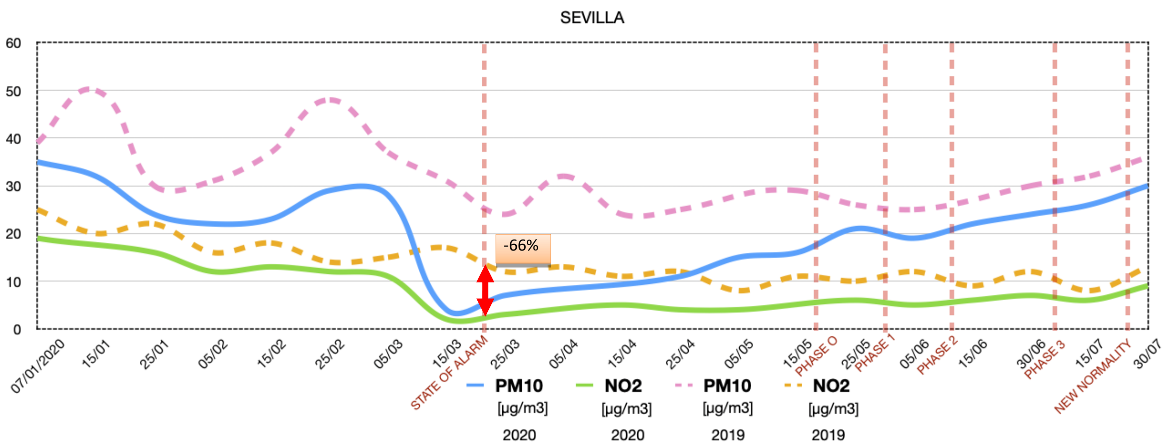


Figure 15. Data comparison of air pollutants in Sevilla (measuring station of Santa Clara) referring to 2020 its comparison with 2019

2.5 Analysis of air quality in Bilbao

In spite of being a small city compared with other cities mentioned in this article, Bilbao has high levels of pollution due to a large amount of traffic and connections that take place in this city. In terms of airborne pollutants, the tendency is the same as in other large cities, this tendency is shown in Figures 16 and 17. In the first figure it shows how the current year started with values reaching up to 45 µgr/m3, while on the 14th of march, there is a drastic fall of these values which creates an important point. With the mobility reduction and less industrial activities, the city shows a better air quality with values of PM_{10} and NO_2 around 7 and 5 µgr/m3, data extracted from the air quality data platform (AQICN 2020)

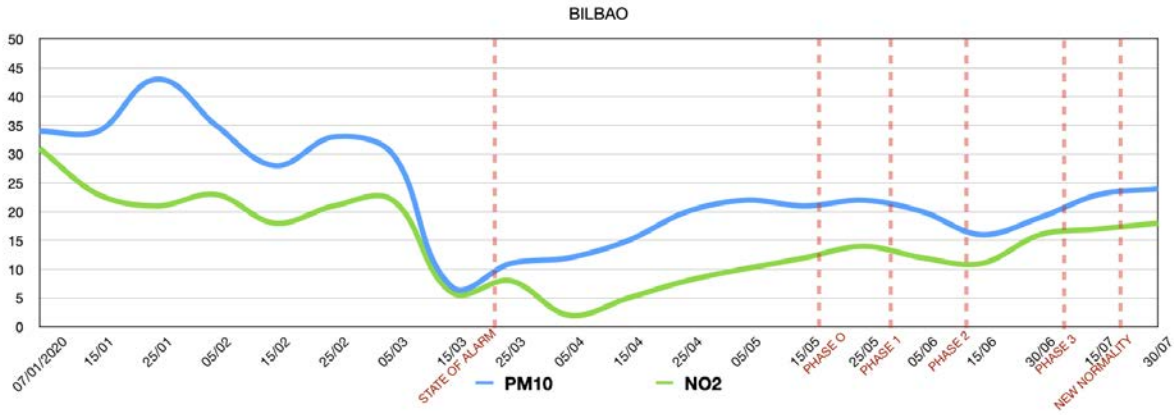


Figure 16. Graph of PM_{10} and NO_2 in Bilbao (measuring station of Mª Díaz Haro) in five different stages. First without awareness of the pandemic from January to March. After the decree of alarm and mobility restrictions (14/03/2020). And the different phases of de-escalation from phase 0 to new normality.

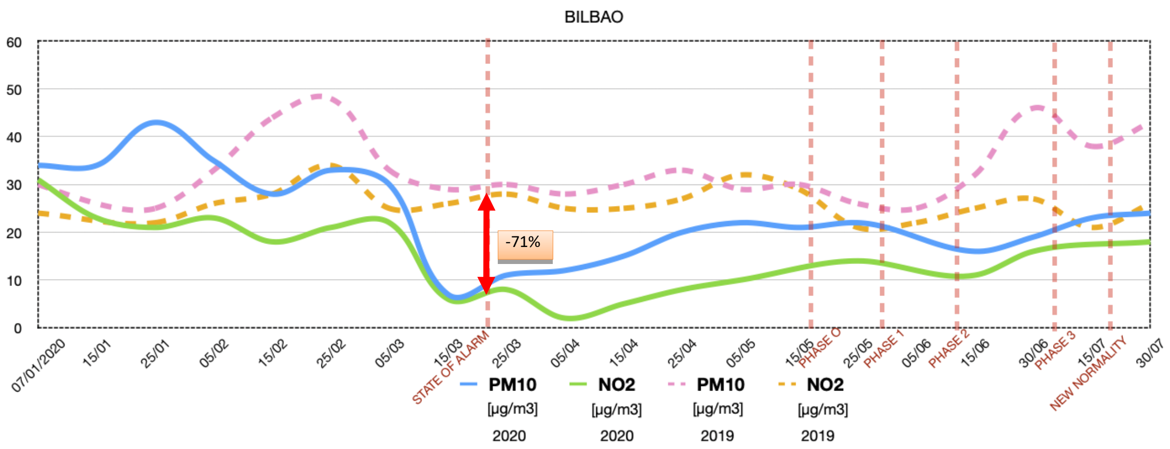


Figure 17. Data comparison of air pollutants in Bilbao (measuring station of Mª Díaz Haro) referring to 2019 its comparison with 2020.

4. Discussion.

In order to reduce COVID-19 expansion, measures such as traffic restriction, flight cancelations, or factory closures are applied. This has had a positive impact on the environment with less carbon dioxide released into the atmosphere and other pollutants. The same measures applied in China in February allowed emissions to decrease by 25%. In this period, China emitted 150 million metric ton of CO_2, less than the quantity recorded a year ago, in 2019, also a reduction in Nitrogen dioxide (NO_2) concentrations have decreased. Italy being the second country with the highest number of confirmed cases of COVID-19 in the world experimented with the same measures with positive results in terms of the environment. The images from the European Space Agency satellite, captured from January 1st until March 11th, 2020, show the diminution of NO_2 in China after the lockdown measures began to apply. Similarly, this situation also occurred in cities such as Italy and Spain where mobility and company operations were restricted.

There is a significant fall in atmospheric pollution observed by satellite images (ESA 2020) in Spain, which minimizes the pollutant concentration in large cities of the country. As a consequence of activity decrease, there is a clear reduction in NO_2 and PM_{10} along with lower electricity consumption, which leads to emission reduction by power plants that use fossil fuel.

The city of Valencia (Spain) has observed an immediate reduction of pollutants. Valencia has seven measuring stations, located on"Avenida de Francia, Bulevar Sur, plaza Ayuntamiento, el Molí del Sol (Campanar), Pista de Silla, Universitat Politècnica and Viveros".These stations measure the main pollutant sources present in urban environments such as sulfur (SO_2) and nitrogen oxides (NO, NO_2, NOx), carbon monoxide (CO), Ozone (O_3), and the suspended particles with fractions less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2,5}$), and organic compounds (VOCs, benzene, toluene, xylene). Paying particular attention to nitrogen oxide (NO_2) and PM_{10} measured during holidays, NO_2 pollution levels are reduced by up to 90% in Pista de Silla on 22/03/2020 (holiday after mobility restriction order) where by measuring it was shown 1 µgr/m^3 in reference to another holiday prior to the mobility restriction on (8/03/2020) where by measuring it was shown 12 µgr/m^3. This difference is even more significant if it compared to holiday dates in January 2020 where 16 µgr/m^3 (18/01/2020), when there was still no special awareness on the pandemic problem by the citizens.

Analyzing the NO_2 concentrations on working days in Valencia, it can be the observed measurement of de 3 µgr/m^3 on 20/03/2020 (working day after the decree of mobility restriction), having an average reduction of 79% compared to next week (12/03/2020) where values of 19 µgr/m^3 were measured, or an average reduction of 85% in the month of January (24/01/2020) 21 µgr/m^{3,} when there was still no special awareness on the pandemic crisis by the citizens.

In one week, PM_{10} suspended particles have been reduced by up to 55% compared to holidays, and up to 70% compared to working days. This reduction is more significant if compared with the same days of January 2020 or compared to 2019 measurements.

The annotations on the city of Valencia can also be discussed regarding the city of Barcelona, where you can see some decreases on holidays of NO_2 and PM_{10}. NO_2 pollution levels on holidays are reduced from 22 µgr/m^3 (18/01/2020) to 4 µgr/m^3 (22/03/2020). comparing NO_2 on workdays, it goes from 31 µgr/m^3 (12/03/2020) to 9 µgr/m^3 (20/03/2020). PM_{10} levels on holidays are reduced in Barcelona from 28 µgr/m^3 (18/01/2020) to 15 µgr/m^3 (22/03/2020). Comparing PM_{10} on workdays is passed from 50 µgr/m^3 (24/01/2020) to 17 µgr/m^3 (20/03/2020).

Graphically, it can be seen in Figure 18, elaborated with information extracted from air quality data platform (AQICN), the significant reduction of PM_{10} concentrations in the five Spanish cities analyzed (Madrid, Barcelona, Valencia, Bilbao, and Sevilla), comparing one month prior to the lockdown and after lockdown.

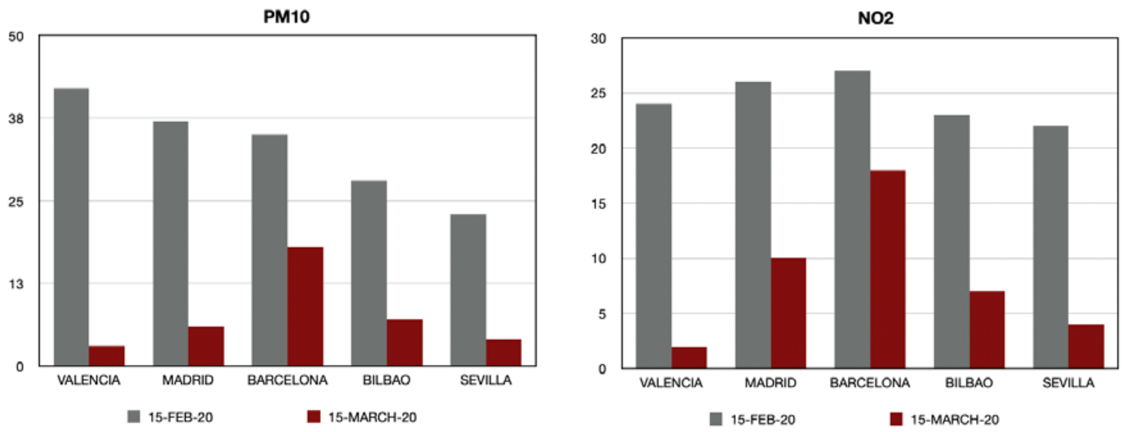


Figure 18. PM_{10} and NO_2 concentrations (µgr/m^3) on working days in Valencia, Madrid, Barcelona, Bilbao, and Sevilla. In grey, before the decree of alarm and mobility restrictions

(15/02/2020). In red, after the decree of alarm and mobility restrictions (15/03/2020). Source: own elaboration.

A mobility restriction has caused a decrease in private traffic, being this one of the main factors of urban air pollution, all this shows a significant drop in suspended pollutant particles.

There has been a significant reduction in polluting particles according to the recorded data. This reduction occurred on March 15th, the first day of effective quarantine (domiciliary confinement was ordered), in comparison to the previous week without any substantial change in the dispersion meteorological conditions between both dates.

In the case of Spain specific days (before and after lockdown) have been analyzed for data comparison. It is always observed a significant reduction in air pollution. This result reinforces the significant impact of human activity on the environmental quality of cities (Gómez et al., 2018; Condereff project, 2020; Grow Green project, 2020), and highlights the importance of seeking formulas to make the environment where we live more sustainable (Peñalvo-López et al 2020; Cárcel-Carrasco et al 2020; Peñalvo-López et al 2019; Peñalvo et al 2017), combining mobility freedom with environmental respect.

5. Conclusions

Based on the analysis and data collection of air pollutants (PM_{10} and NO_2) from different regions of Spanish territory, it has been prepared a comparative study in order to display the influence of traffic and human mobility on air quality. This study was conducted during and after the lockdown period. This same period of time has been compared to the year 2019 when there was no confinement. The pattern of pollution was altered during the lockdown period such as a decrease in air pollutants was shown over different cities (Venter et al., 2020).

The COVID-19 pandemic clearly shows the interconnection between human and planetary health (Web 3 2020). Despite being in the technological era, humankind struggled against the health disaster which abruptly appeared. To control this pandemic most countries adopted, as an effective measure, the lockdown on social and economical activities in order to avoid the transmission of the virus. All this shows a significant drop in suspended pollutant particles. First, a drastic decrease in pollution in China was observed, later on in Italy and almost immediately in Spain. Due to the pandemic crisis and actions taken by the Spanish government, the electricity demand has been considerably reduced up to 25% compared to January, referring to the week after applying the alarm state (14/03/2020). This implies lower pollutant emissions as a consequence of electric power production plants.

Regarding the air pollutants and its analyzed data in this article indicates the downturn of pollutants such as PM_{10} and NO_2, reaching the average values of reduction of 70 to 80% taking into account dates after the decree of alarm and mobility restriction by the Spanish government (14/03/2020), compared to days prior to that date. The decline of these pollutants shows a similar tendency in all Spanish cities where the period after the lockdown was identified by the reduction values of PM_{10} in Valencia of 88,89%, in Madrid of 87,5%, in Barcelona the reduction in PM_{10} was 70%, in Sevilla 86,8% and in Bilbao of 87,8%. The same tendency was shown for NO_2.

It must be considered the rising of pollution levels once the economy is reactivated. However, this situation can be controlled by taking necessary measures to reduce greenhouse gas emissions and environmental pollution in large cities. It is remarkable the long-term impact from the emergence of COVID-19 which demands the reshaping of environmental policies in order to improve the air quality mainly in urban areas.

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