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A vision on air pollution in cities and the human effect

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ABSTRACT

The human effect on air quality in cities and the evolution of air pollution is obvious, due to economic activity, vehicle traffic, etc. The situation created indirectly by COVID-19, has caused many countries to impose during certain periods restriction of movement and stoppage of economic activities, which has allowed us to observe the instant effect that occurs on the air quality in cities. This article discusses what the observed effect has been, focusing on the early moments of the pandemic (January 2020 to March 2020), with an analysis of the situation from its origin in China to its arrival in Europe and more specifically the situation created in Spain. After the analysis of the situation, it can be seen the large reduction of pollutants in the air of different cities, and in particular in Spain, which came to reduce about 80%. All this leads us to the observation of how human activity can greatly influence air pollution.

KEYWORDS
air pollution, COVID-19, cities energy, environment

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1. INTRODUCTION

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, 2020; Miller, 2020; Myllyvirta, 2020).
The reduction of industrial activity and transportation with combustion engine vehicles associated with the COVID-19 (Gatto et al. 2020; Web 1; Web 2 and Web 3) crisis is also showing positive side effects on the environment and human health at a smaller scale. The distribution of the affected countries is shown in figure 1, originated in China and the affected countries as of March 19th, 2020 (Mahase, 2020; Web 1). Satellite images show the reduction of CO2 up to 25% in China due to the coronavirus crisis (approximately 200 million tons) (USEP, 2020). After the pandemic impact on Italy, satellite images taken by the European Space Agency (ESA) show the decrease of pollutant concentration in, such as nitrogen dioxide CO2 (ESA, 2O2O) (a toxic compound that affects negatively the air quality, in addition to be a greenhouse gas) in the country. These satellite observations are an example of how the pandemic has reduced emissions of gases produced by the human activity, first in China, and then, in Italy. In Spain, 10.000 annual deaths are caused by air pollution, a value much higher than the mortality associated with traffic accidents, which is 1,700 deaths per year, according the Spanish Society of Pneumology and Thoracic Surgery (SEPAR) (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) (WHO, 2020). The most harmful environmental pollutants are nitrogen dioxide (NO_2), which causes the most deaths in Spain (around 6,000 a year), followed by suspended particles matter (2,600 annual deaths) and tropospheric ozone (more than 500) and others like sulfur dioxide, carbon monoxide or lead (WHO,2020). Researchers that study the impact of greenhouse gas emissions on climate crisis and human health are now working to understand the possible effects of the pandemic in the future.
A reduction of air pollutant is common during times of crisis (McKinney, 2019; Muhammad, 2020; Web 4). This is due to less mobility of people and transportation among with the reduction of economic activities that depend on fossil fuel, responsible for CO2 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 has overcome. The International Energy

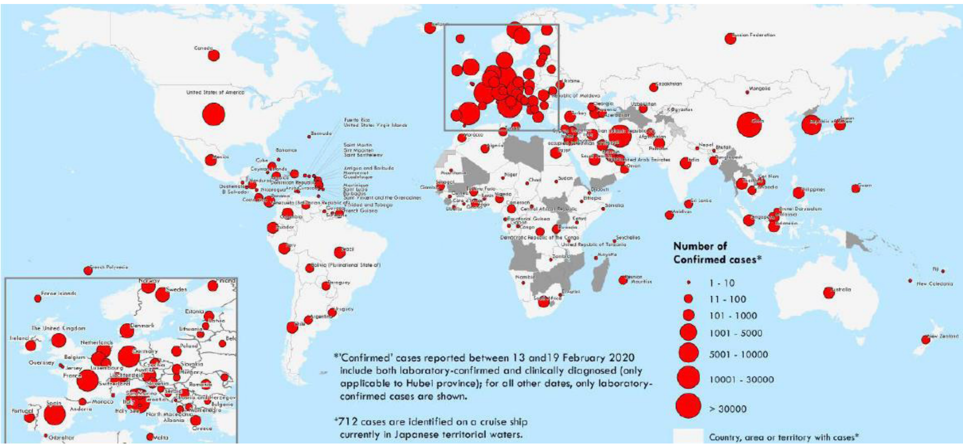

Figure 1.
Countries, territories or areas with reported confirmed cases of COVID-19, March 19th 2020 (Web 1).

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 economy, contamination levels will rise again. However, this situation can be controlled by taking necessary measures to reduce greenhouse gas emissions. This article aims to give an insight into how human activity influences the air quality of cities intensively. Given that because of the influence of the COVID-19 pandemic, many countries have restricted the movement and activity of citizens at different times, this has served as an experimental basis for observing the significant effect that has occurred. To this end, we analyze the first moments of these measures (between January and March 2020), by observing satellite images and measuring data with pollution measurement stations, observing the significant reduction of air pollution in cities as an effect of reduced movement due to the state of alarm and lockdown of citizens.

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 consideration:

- The European Space Agency (ESA) and NASA pollution monitoring satellites (ESA, 2020; IEA, 2020). These satellites allow visualizing some side effect of the pandemic associated to air pollution of different regions.
- Atmospheric pollutants measurement station of Madrid, Barcelona and Valencia (Spain) (AQICN, 2020).

The stations measure the main pollutant sources present in urban environments such as nitrogen oxides (NO, NO_2, NOx), sulfur (SO_2) Ozone (O_3), and carbon monoxide (CO), and the suspended particles with fractions less than 10 microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$), and organic compounds (VOC_s, benzene, toluene, xylene). Nitrogen oxides (NO_2) and PM_{10} require special attention. The weather station GAIA-A13 is normally used for measurements.

3. THE EFFECT COVID-19 ON AIR POLLUTION AND THE ELECTRICITY DEMAND

It is important to analyze the basic consequences of the pandemic in the countries that have previously suffered from COVID-19 (Sharifi et al., 2020), such as China, Italy and Spain. China is the country that registered the first COVID-19 cases at the end of December 2019, establishing the closure of factories, shops and travel restrictions to cope with the epidemic, these actions caused a substantial decrease in fossil fuel consumption since January. Satellite images from NASA and the European Space Agency reveal drastic drops in nitrogen dioxide as people stayed inside their homes and industries slowed down or were closed.

European Space Agency (ESA) and NASA have detected significant decreases in nitrogen dioxide (NO_2) in China through pollution monitoring satellites. There is evidence that the change is related with the economic slowdown as a consequence of coronavirus outbreak (ESA, 2020).

NO_2 values can be seen in the figure 2 of China from January 1st to 20th, 2020 (before quarantine) and from February 10th to 25th (during quarantine). The data was collected by the Tropospheric Monitoring Instrument (TROPOMI) on Sentinel-5 satellite of ESA, a related sensor, the Ozone monitoring Instrument (OMI), and Aura satellite of NASA, making similar measurements (NASA, 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. According to 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).

A study carried out in China by a group of experts from the Finland-based Center for Research on Energy and Clean Air (CREA) ensures that during the weeks of lockdown, until March 1st, carbon dioxide emissions fell by a 25%, this means approximately

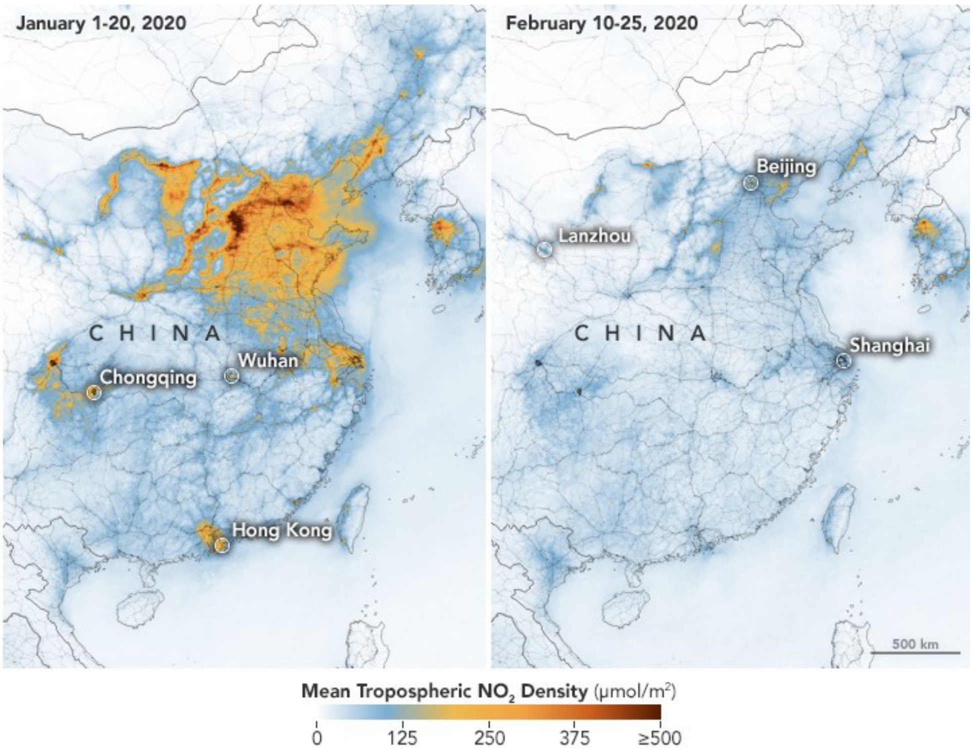

Figure 2.
Significant decreases in nitrogen dioxide (NO_2) over China. January 1st - February 25th, 2020.

200million tons (Web 5). The reduction produced in the consumption of coal and oil shows a reduction of at least 25% in emissions compared to the same period in 2019, equivalent to a reduction in 6% of global emissions during the period.

In Europe the effect of air pollutant decrease has been also observed in large urban areas as a consequence of mobility restriction and economy paralyze, first in Italy and then in Spain.

Observing the satellite images (Fig. 4) from the Tropomi instrument, on board the Copernicus Sentinel-5P satellite (ESA, 2020), it can be seen the density of pollution in various regions before and after the strict lockdown of citizens. Observing the concentrations of Nitrogen Dioxide (NO_2) and other air pollutants from January 1st to March 11th, 2020, it can be seen the decrease in air pollution in cities in a short period of time (few weeks). This indicates the strong impact produced by human activity, due to emissions from exhaust pipes and production of electricity, especially coal-fired power plant. These NO_2 emissions have been reduced as a result of restrictions in mobility as many companies or factories shut down, therefore less energy was consumed. All these measures were taken to prevent the spread of infection between citizens.

It can be seen (Fig. 3) that in northern Italy the pollution gases level has decreased considerably. In Spain occurred the same as it is observed a clear reduction in pollution, with greater intensity in large cities such as Madrid, Barcelona or Valencia after the measures for raising public awareness and decree of state of alarm approved by Spanish government in March 2020.

Satellite images show the concentration of NO_2 (redder in figure 3 at higher concentration in that

area) have been greatly reduced in northern Italy between mid-January and mid-March 2020, just as this reduction can be seen in Spain, mainly in large cities (ESA, 2020). The reduction of NO_2, which is one of the most harmful substances expelled by vehicles (especially diesel), is clearly seen in northern Italy and major Spanish cities, coinciding with the state of alarm and lockdown of citizens produced to prevent COVID-19, with the stoppage of the economic activity.
Although it could have slight variations in the observed data in figure 4 due to cloud cover and climate change, the figure also shows the reduction of emissions which corresponds to the blockade in Italy that results in less traffic and industrial activities.
In Spain, the electricity demand (REE, 2020), by observing the three stages of the crisis, first, when there was not a public awareness of the COVID-19 impact (A-mid-January 2020), second, after the first alert by Spanish Government (B- early March 2020) and third, after the decree of state of alarm and mobility restriction of the citizens by the government (C-mid-March 2020). The figure 4 shows the evolution of electricity demand due to the pandemic crisis and actions taken by 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

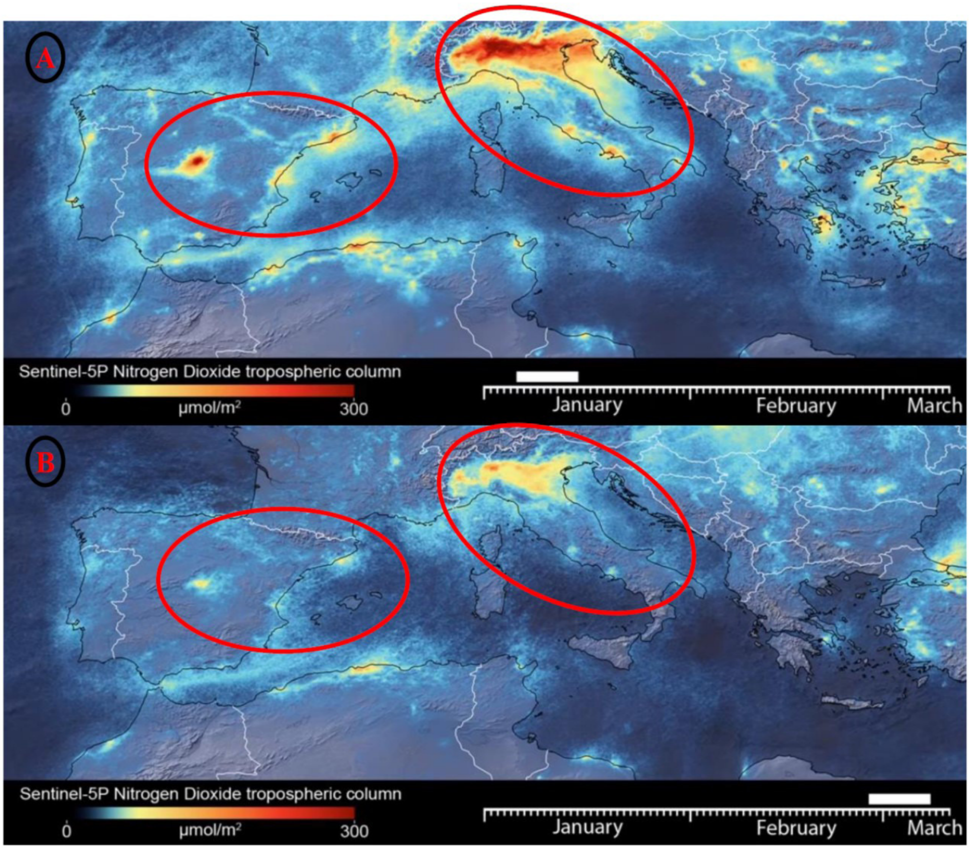

Figure 3.
Satellite views of nitrogen dioxide emissions (NO2, redder on the map at high concentration). Top image (A-early January), bottom image (B-mid-March) (ESA, 2020).

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. The last day analyzed was 5 days after the state of alarm, and it is foreseeable that more economic activity will stop. This implies lower pollutant emissions as a consequence of electric power production plants.

4. A VISION ON AIR POLLUTION IN CITIES AND THE HUMAN EFFECT (CONSEQUENCE OF THE STATE OF ALARM AND LOCKDOWN)

Observing air quality of three Spanish cities (Madrid, Barcelona and Valencia) through air pollution monitoring stations, it is shown the significant decrease in pollutants, especially NO2, consequence of the drastic traffic reduction due to mobility restriction ordered by the Spanish government as of March 14th,

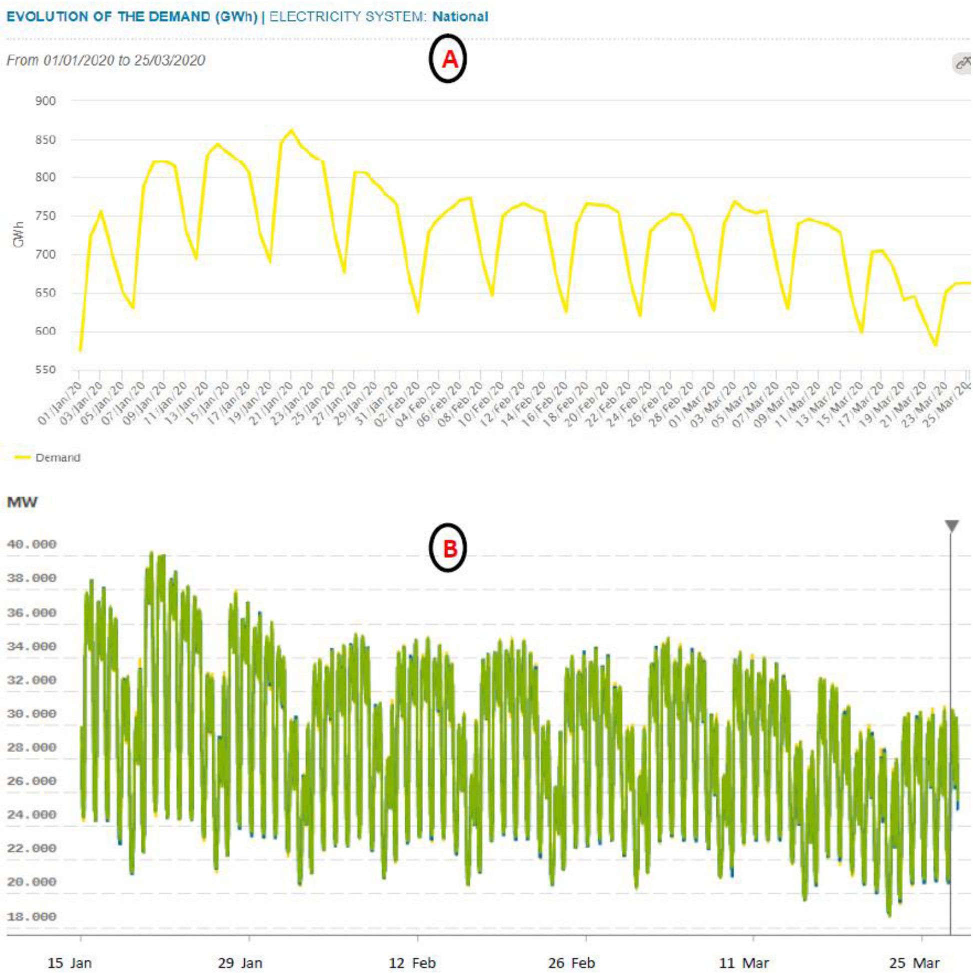

Figure 4.
Electricity demand in Spain between January and March (A) and maximum power between January and March 2020 (B).

2020. In figure 5 it can be observed the decrease of approximately 75% reduction in NO2 concentrations in Madrid (Spain) (PCA, 2020), comparing figure 5A to 5C. This reduction is particularly significant at stations located in traffic environments (Web 6), compared to reductions observed in other urban air pollution monitoring stations during the alarm state.

This is motivated by the sharp reduction in vehicle traffic due to restrictions on movement to citizens. As an example, figure 6 shows the significant reduction in traffic in three environmental monitoring zones in Madrid, where traffic reduction has been able to reach up to 80% (AYM, 2020).

Nitrogen dioxide (NO2) is a pollutant indicator of transport activities, especially road traffic. It is emitted directly by vehicles, especially diesels (direct or "primary" emissions) but is also produced in the atmosphere by a chemical process such as nitrogen monoxide (NO) oxidation, also emitted primarily by vehicles; in this case it is secondary nitrogen dioxide.

In Madrid, it notes that there has been a significant decrease in NO2 levels during the lockdown period decreed by the state of alarm. Thus, in the period from January to July you can see in figure 7 the decrease in levels of NO2, reaching average levels below the limit value at the 24 stations of the air quality monitoring network in Madrid (AYM, 2020).

This impact can be better understood by observing low levels in average NO2 concentrations during the alarm state in figure 7.

As for the concentrations of PM10 and PM2.5, formed by a complex mixture of components with diverse chemical and physical characteristics, formed from other primary pollutants and even from natural elements. In European cities, this material is generated in combustion processes from both building heating systems and emissions generated by road traffic, with particular importance in diesel cycle engines with engine technologies prior to 2000. The contribution of traffic encompasses both the direct emissions of primary particles from the exhaust pipe of motor vehicles, as well as the resuspension of materials that accumulate on the pavement (mechanical abrasion products of vehicles, brakes, wheels, emissions derived from construction or demolition works,

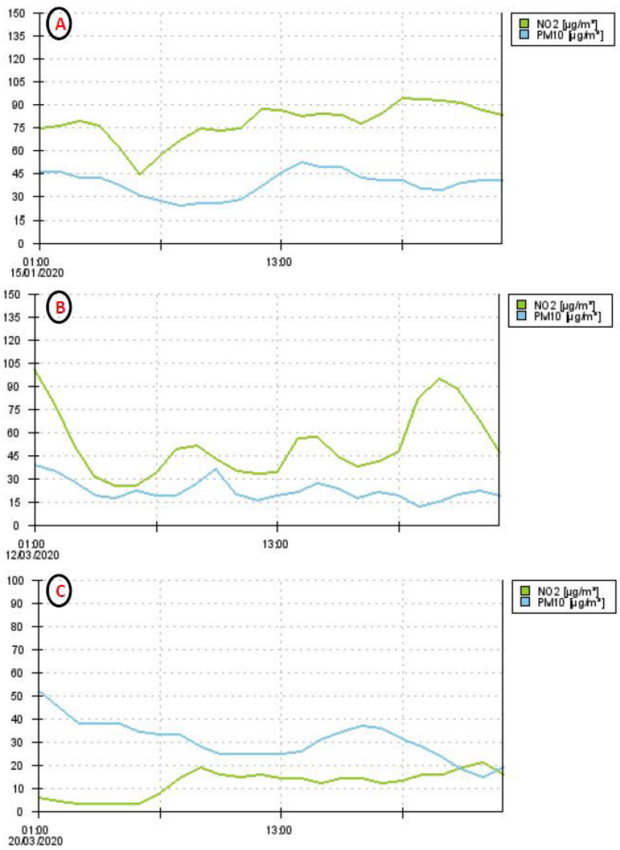

Figure 5.
Chart of air pollutants in Madrid (measuring station of Escuelas Aguirre) in three different stages. A) Without awareness of the pandemic problem (15/01/2020). B) After first awareness of the crisis (12/03/2020). C) After the decree of state of alarm and mobility restrictions (20/03/2020).

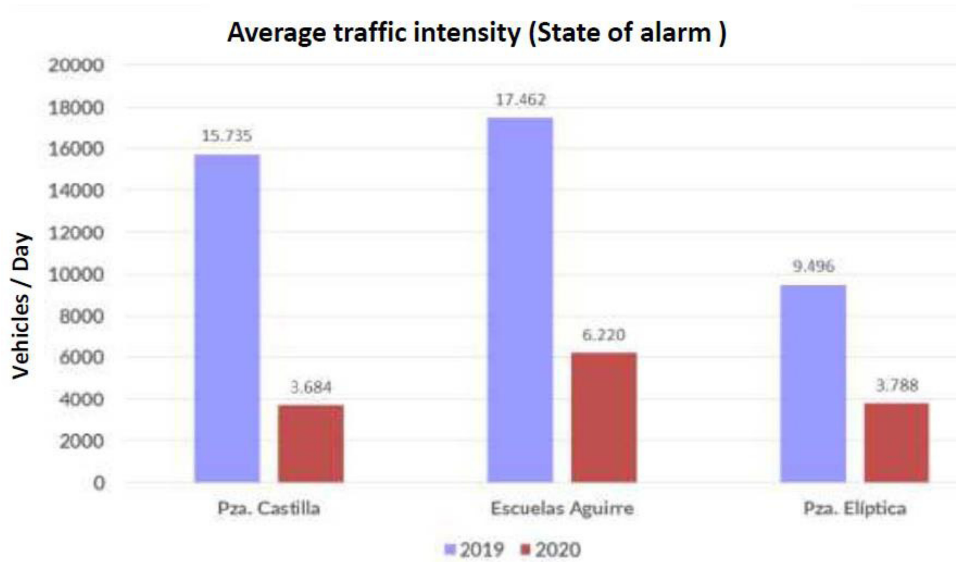

Figure 6.
Comparison of Average Traffic Intensity (I.M.D.) at three selected traffic measurement stations in Madrid during the alarm status, in comparison with the same period in 2019. (AYM, 2020).

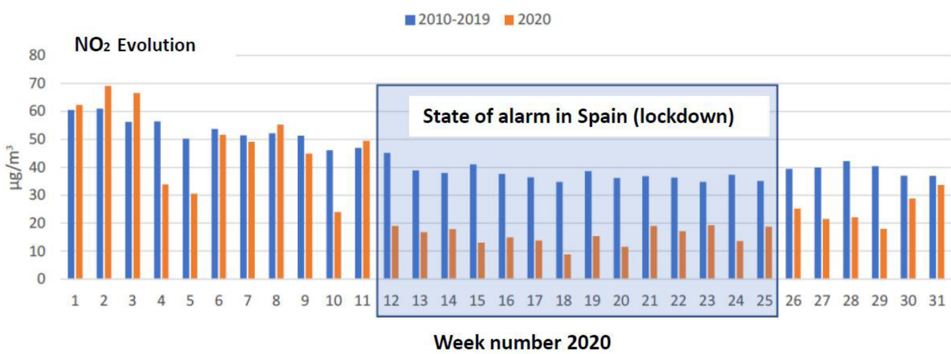

Figure 7.
Comparison of Average Traffic Comparison of average nitrogen dioxide values (NO2) at measuring stations in Madrid in the period from January 1st to July 31st , 2020, with the average of NO2 of the same period for the years 2010 to 2019, inclusive (AYM, 2020).

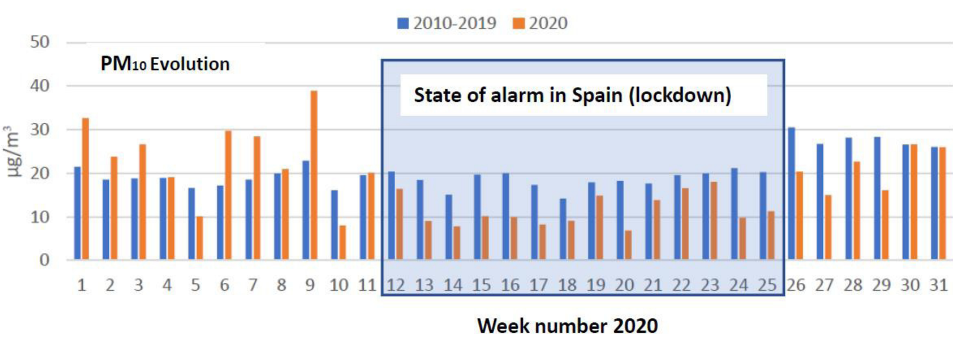

Figure 8.
Comparison of mean PM10 particle values at traffic stations in Madrid in the period from January 1st to July 31, 2020, with the average of PM10 for the same period for the years 2010 to 2019, inclusive (AYM, 2020).

etc.). In addition, in the case of Spain, because of its geographical location, natural contributions from the Sahara Desert can be found through intrusions of African air.
The term PM10 refers to suspended particles with an aerodynamic diameter of up to 10 μm, comprising the thin and thick fractions, and PM2.5 to suspended particles with an aerodynamic diameter of up to 2.5 μm.
These reductions are also noticeable in all types of air pollution monitoring stations in Madrid, being more noticeable in stations located in traffic areas, although they are not as significant as in the case of NO2, as they may be conditioned by other activities that take place in the environment or by the contribution of Saharan air intrusions (AYM, 2020). During the state of alarm and lockdown period, there is a noticeable reduction in PM10 concentration values compared to the measurements made in 2019 (Fig.8) in the city of Madrid.
By way of example, figure 9 shows the evolution of major pollutants: NO2 and suspended particles (PM10 and PM2.5) at the Air Quality Station in Plaza Elíptica (Madrid) in the period from 1st January to 31st July 2020, in comparison to the same period in 2019.
In the same way as Madrid, observing the air quality data through atmospheric pollution monitoring stations in Air quality Historical Data Platform (AQICN, 2020).) (Grow Green, 2020) (Fig. 10, Fig. 11, Fig. 12, Fig. 13) in the city of Valencia and Barcelona, it can be observed a decrease in pollutants especially the NO2, as a consequence of drastic traffic reduction. NO2 is originated by the combination of nitrogen and oxygen present in the air as a consequence of combustion processes, including road traffic, while PM10 particles are also originated during combustion processes (carbonaceous particles, soot), although they can also have natural origin (fine sand and other particles) carried by winds.

5. DISCUSSION

In all the cases shown in this paper, it is observed that there has been a significant reduction in traffic intensities during the state of alarm period, leading to a very significant reduction in the levels of concentration of pollutants, especially nitrogen dioxide (NO2). In the case of particulate matter (PM10 and PM2.5) it does not generally result in such significant decreases, as they may be caused by other activities that develop in the environment or episodes of Saharan dust intrusions.
Looking at satellite images from different areas (ESA, 2020), the significant reduction in air pollution is checked at the time that mobility reduction measures have been implemented due to the lockdown of people by the effect of COVID-19, which has

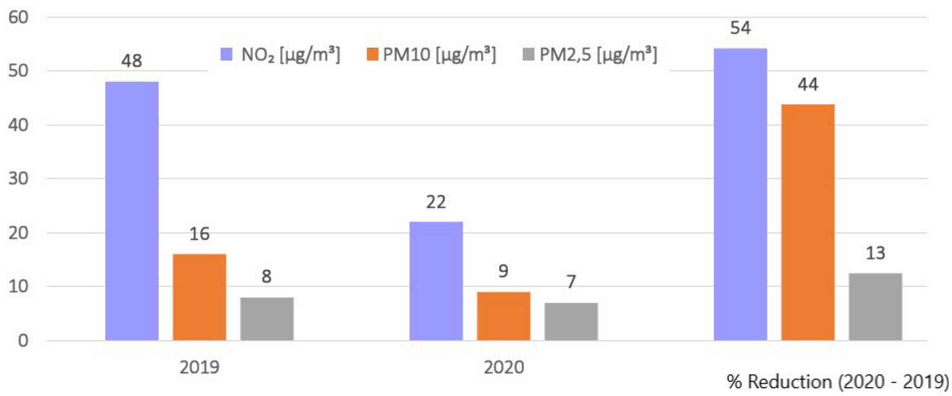

Figure 9.
Variation of the levels of NO2, PM10 and PM2.5 at the air quality station of Plaza Elíptica in Madrid during the state of alarm (March 15th to June 21st , 2020) compared to the same period of 2019. (AYM, 2020).

Figure 10.
Measurements of the meteorological station "Pista de Silla-Valencia-Spain", of daily values of NO2 during 2019 and until March of 2020.

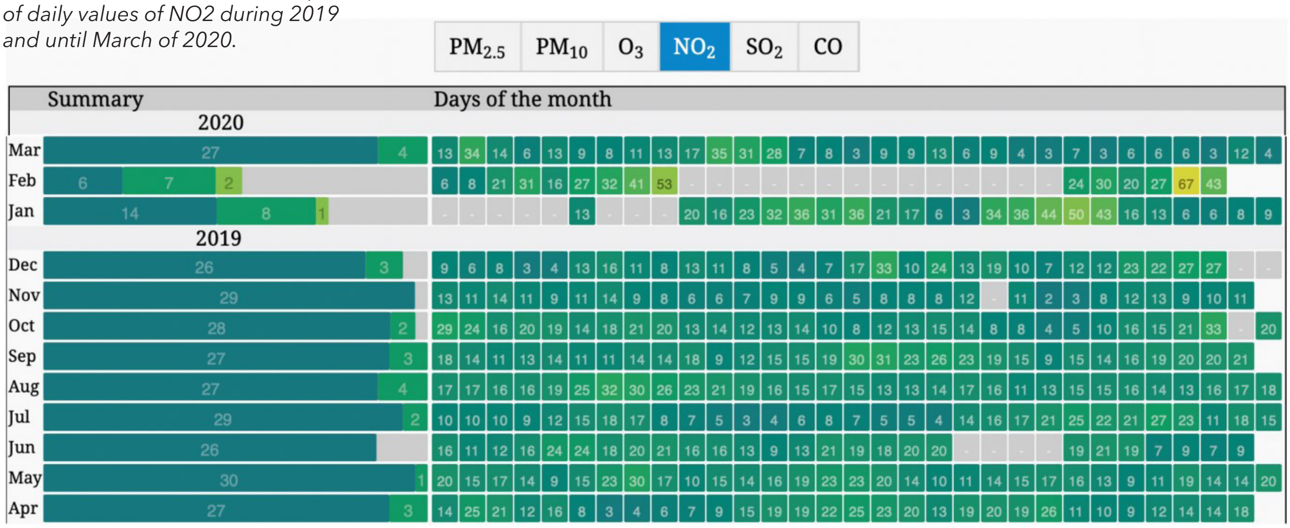

Figure 11.
Measurements of the meteorological station "Pista de Silla-Valencia-Spain", daily values of PM10 during 2019 and until March 2020.

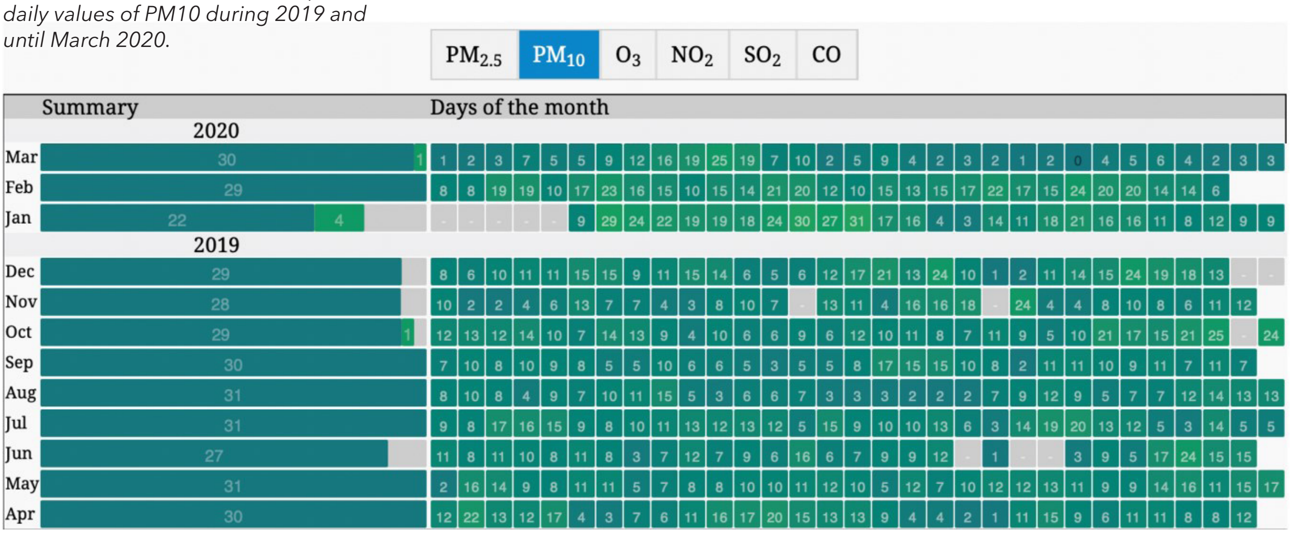

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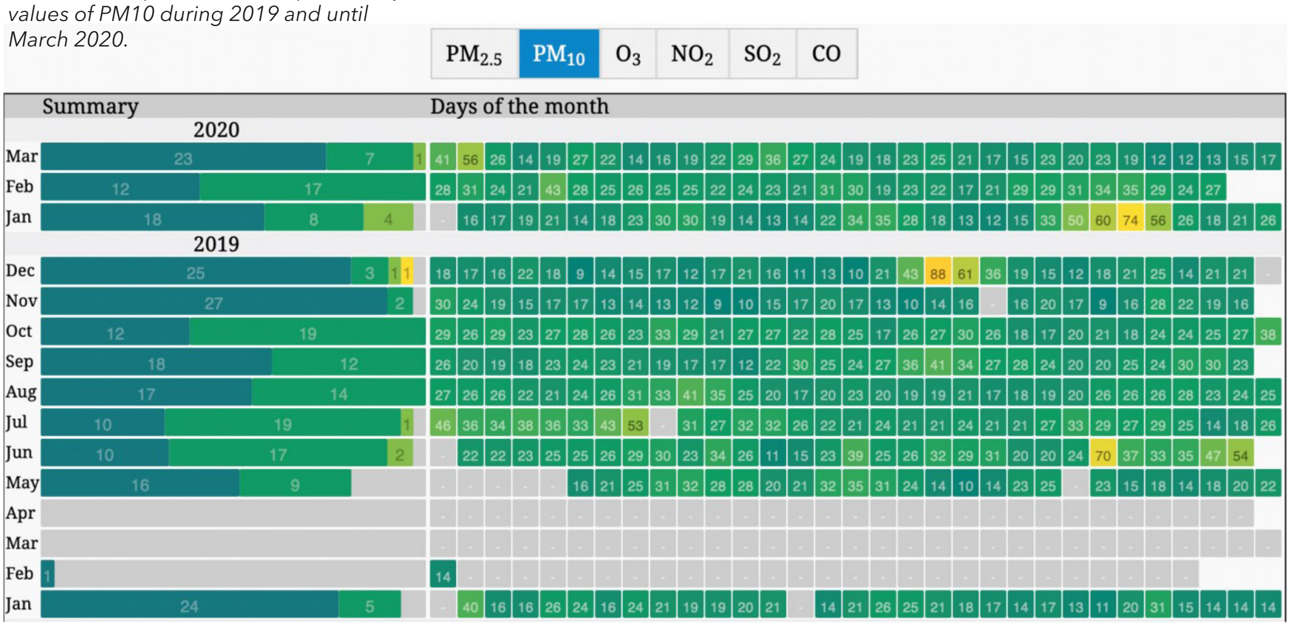
Figure 12.
Measurements of the meteorological station "Eixample-Barcelona-Spain", of daily values of NO2 during 2019 and until March of 2020.

Figure 13.
Measurements of the meteorological station "Eixample-Barcelona-Spain", daily values of PM10 during 2019 and until March 2020.



significantly reduced activity and energy consumption by industries. Observing different air pollution measuring stations in Madrid, and focusing on the stations located in the urban area (Measuring station of Escuelas Aguirre), it is verified that during three stages, which are: after mobility restriction ordered by the Spanish government from March 14th 2020, a NO2 concentration is measured between 10 to 20 µg/m3 on day (20/03/2020), a decrease of approximately 85% compared to the days prior to mobility restriction and partial economic activity stoppage (12/03/2020) where values between 40 to 80 µg/m3 were recorded. Likewise, observing other pollution measuring station located in Madrid (Fig. 1, Fig. 2, Fig. 3, Fig. 4), it can be concluded that the reduction in pollution is generalized throughout the city, as indicated for the measuring station of "Plaza Elíptica".

In the city of Valencia (Spain) there has been an immediate reduction of pollution, both on working days and holidays, if we compare the measures taken of the status of pollutants before and after the lockdown of citizens due to the state of alarm decreed by the Spanish government. NO2 concentrations passed on public holidays from 12 µg/m3 (before lockdown) to 1 µg/m3 (after lockdown). If we compare the concentration of air pollutants on working days, it is reduced from 19 µg / m3 (before lockdown) to 3 µg / m3 (after lockdown) (Fig.11).

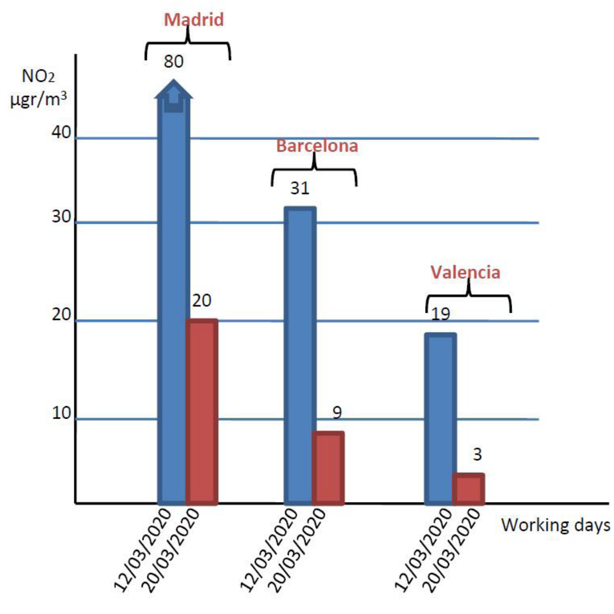
In Barcelona, as discussed about Valencia and Madrid, it can be seen a decrease on weekdays and holidays of the NO2 and PM10 measurements. No2 pollution levels decreased on public holidays from 22 µg/m3 (before lockdown) to 4 µg/m3 (after lockdown). If we compare the concentration of air pollutants on working days, it is reduced from 31 µg / m3 (before lockdown) to 9 µg / m3 (after lockdown). PM10 concentrations have also been reduced.

It can therefore, be concluded that there is a clear link between road traffic and pollutant levels in cities, hence the need for the reduction of motorized traffic and polluting vehicles in order to improve air quality and in order to meet the values set for different pollutants by European and national legislation, especially for nitrogen dioxide.

Graphically, it can be seen (Fig.14), the significant reduction of NO2 concentrations in the three cities analyzed (Madrid, Barcelona and Valencia), comparing one week of difference, before the decree of state of alarm and mobility restrictions (12/03/2020) and after the decree of state of alarm and mobility restrictions (20/03/2020).

The lockdown of citizens and the stoppage of activity has led to a decrease in private traffic, this being one of the main factors of urban air pollution, causing a large decrease in concentrations of NO2 and other polluting particles. If we look at the data obtained by the pollution measuring stations, comparing other days, we reach the same conclusions (strong reduction of pollution as a result of the stoppage of human activity) These observations show the visible impact of human activity on air pollution (Grow Green, 2020; Condereff, 2020; Gómez, 2020; Peñalvo, 2020 a) motivating for the search of new ways to improve air quality in city environments (Cárcel, 2020; Peñalvo, 2020b; Peñalvo, 2020c).

Figure 14.
NO2 concentrations on working days in Madrid, Barcelona and Valencia. In blue, before the decree of state of alarm and mobility restrictions (12/03/2020). In red, after the decree of state of alarm and mobility restrictions (20/03/2020).



6. CONCLUSIONS

Satellite images clearly show the strong impact on air pollution in cities caused by people. This indirect effect caused by the situation of COVID-19 which led to a noticeable reduction in air pollution in a short period of time (few weeks).
In some of the Spanish cities observed, this reduction in pollution levels has been able to reach levels above 80%.
This article shows, in a basic way, that the effects produced by human activity affects pollution in cities in a very significant way, observing that the effects of reducing air pollution previously observed in China and Italy are confirmed in Spain. This should serve as a warning to social awareness, in changing lifestyle habits that improve the quality of the environment where we live.
Solutions and ways of managing the city environment should be sought to improve air quality, reducing polluting traffic and increasing the weight of renewable energy for the sustainability and life quality of the population.
The changes in air pollution are seen as benefit caused by the pandemic indirectly and do not take into account any other negative effects that may occur on the economy and the social changes that this will entail.
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