The impact of COVID-19 in air quality worldwide: a systematic review

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ABSTRACT: WHO had announced on the 11th of March that COVID-19 was considered a pandemic disease. At this stage, around 37 million cases and one million deaths were confirmed worldwide (in October 2020). To try to avoid the contagion of the population, all governments around the world had applied several social and hygienic recommendations, as well as mandatory measures. All of this had a huge impact not only on people's lifestyles but also on the environment. Based on PRISMA methodology, this study aims to identify the main impacts of coronavirus on air quality. Seven articles had accomplished all inclusion criteria and were deeply studied. In general, all air quality pollutants had decreased during the (partial) lockdown, showing a positive impact on air quality worldwide. In areas associated with urban traffic, the differences before/during lockdown became significant for the CO (-53.1%), PM_{10} (-22.8%), $PM_{2.5}$ (-29.8%) and NO_2 (-54.3%). Similar results were observed all around the world. Although this statement, the authors are aware of the extremely negative impact that all this situation has on the social and economic point of view.

Keywords: COVID-19; Coronavirus; Air quality; Air pollution; CO; PM_x; NO_2

Impacto do COVID-19 na qualidade do ar a nível mundial: uma revisão sistemática

RESUMO: A Organização Mundial da Saúde anunciou no dia 11 de março que a COVID-19 era considerada uma doença pandémica. Nesta fase, cerca de 37 milhões de casos e um milhão de mortes foram confirmados em todo o mundo (outubro de 2020). Para tentar evitar a propagação do contágio na população, todos os governos a nível mundial aplicaram diversas recomendações sociais e higiénicas, para além de medidas obrigatórias. Tudo isto teve um grande impacto não só no estilo de vida das pessoas, mas também em termos ambientais. Com base na metodologia PRISMA, este estudo teve como objetivo identificar os principais impactos do coronavírus na qualidade do ar. Sete artigos preencheram todos os critérios de inclusão e foram sujeitos a um estudo aprofundado. Em geral, todas as concentrações de poluentes atmosféricos diminuíram durante o confinamento (parcial), mostrando um impacto positivo na qualidade do ar em todo o mundo. Nas áreas associadas ao tráfego urbano, as diferenças antes/durante o confinamento tornaram-se significativas para o CO (-53,1%), PM_{10} (-22,8%), $PM_{2.5}$ (-29,8%) e NO_2 (-54,3%). Resultados semelhantes foram observados em todo o mundo. Não obstante estes resultados, os autores estão cientes do impacto extremamente negativo desta situação do ponto de vista social e económico.

Keywords: COVID-19; Coronavírus; Qualidade do ar; Poluição do ar; CO; PM_x; NO_2

Introduction

A pandemic occurs when a new virus emerges and spreads around the world, and most people do not have immunity. World Health Organization (WHO) had declared a pandemic of SARS-CoV-2. Pandemics are usually classified as epidemics first, which refers to the rapid spread of a disease in a certain region or regions[1]. In the matter of the SARS-CoV-2, the WHO Office was informed of the appearance of the first cases of pneumonia unknown etiology detected in Wuhan City, Hubei province of China, on 31st December 2019[2]. From this date to 3rd January 2020, a total of 44 case-patients with pneumonia of unknown etiology were reported by the National Authorities in China to the WHO[2]. On the 13th of January, Thailand reported its first imported case of lab-confirmed novel coronavirus (SARS-CoV-2) from Wuhan, capable of infecting humans, hereby called COVID-19[2]. On 15th February 2020, the COVID-19 virus arrived in Africa, being Egypt the first African country that confirmed a new case of COVID-19[3]. By the day of the 28th of February of 2020, five new countries reported cases of COVID-19 – Belarus, Lithuania, The Netherlands, New Zealand, and Nigeria. A few days passed, and the evolution of the virus continued, and on 7th of March 2020, the global number of reported cases of COVID-19 exceeded 100,000 cases and five new countries/territories such as Columbia, Holy See, Peru, Serbia, and Togo also reported cases of the disease[4].

Due to this big and severe growth of COVID-19 virus throughout the world, WHO had announced on the 11th of March that COVID-19 was considered a pandemic disease. At this stage around 80,955 cases were confirmed in all China and 37,364 worldwide. On 11th March more than five new countries had reported the first cases of COVID-19, such as Bolivia, Jamaica, Burkina Faso, and the Democratic Republic of the Congo[5]. Figure 1 shows the distribution of the reported cases of COVID-19 around the world on the 29th of April of 2020[6].

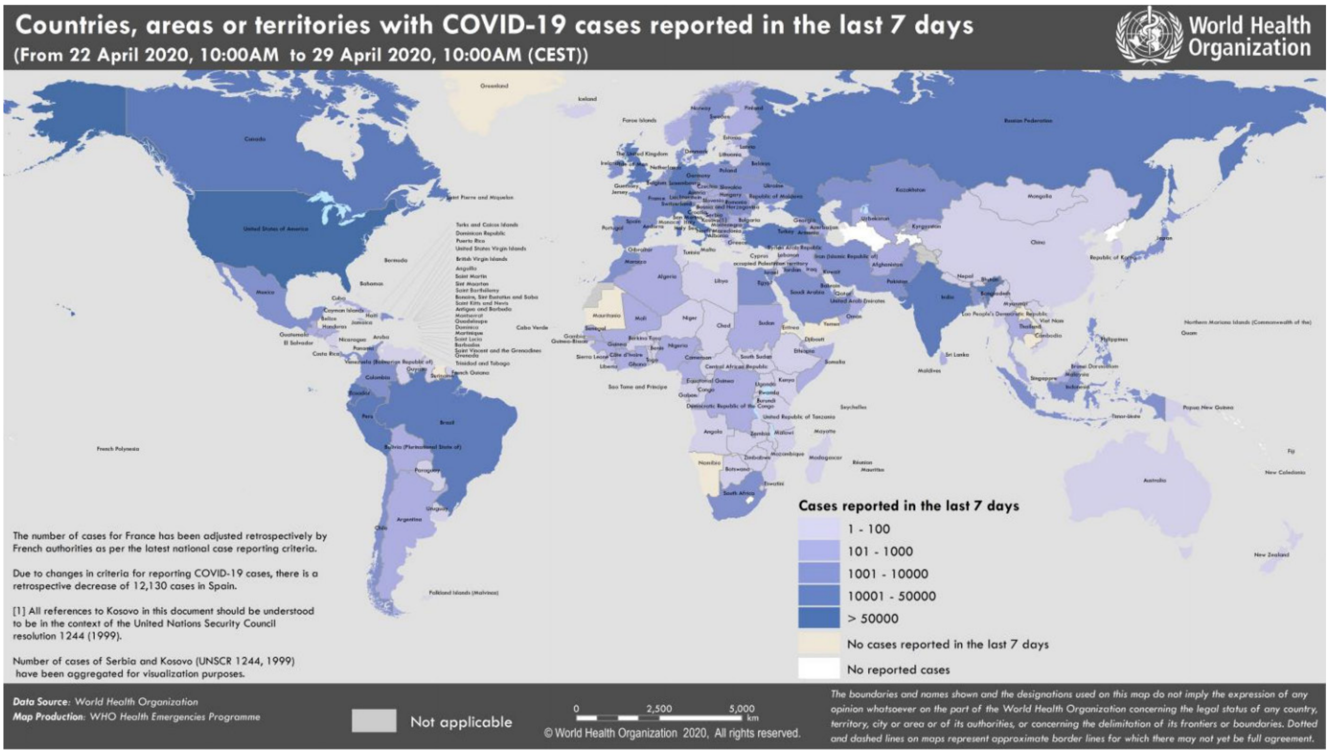

Figure 1. Countries, territories, or areas with reported confirmed cases of COVID-19[7].

Due to this situation, WHO and all affected countries have issued and granted recommendations to avoid infections and the spread of the virus, especially measured that were mainly devoted to elderly people and those who presented pre-existing health conditions: exchange 1-meter greetings; wash hands; regularly clean and disinfect surfaces in the home; limited shared spaces with people aren't feeling well; in case of symptoms of COVID-19, contact your healthcare provider by telephone before visiting; make a plan in preparation for an outbreak of COVID-19 in your community; follow the same preventative guidelines inside and outside of the home and stay up to date using information from reliable sources[7].

Similar measures were applied to the healthy population, being focused on: stay at home (only go out to buy food and medicines and when doing it use the protective equipment correctly to avoid the spread of the virus); frequently wash the hands; maintain social distance; do not touch on the eyes, mouth or face with the hands[7]. It is important to notice that the implemented measures in most countries of the world led to a huge impact on the environment, positively speaking. The World Health Organization (WHO), in 2016, reported that 4,2 million deaths have been caused by ambient air pollution across the world. In this situation, air pollution is estimated to cause approximately 29% of lung cancer deaths, 24% of stroke deaths, 25% of heart disease deaths, and 43% of other lung diseases[7]. In addition, air pollution has attributed to 26% of respiratory infection deaths, 25% of chronic obstructive pulmonary disease deaths, and about 17% of ischemic heart disease and stroke[8]. In China, one of the biggest polluted countries in the world, the main driving activity of air pollution in China is attributed to coal-burning[8]. In the case of the province of Hubei in China, the implemented measures passed, beyond social distancing, to closed industries and powerplants. All these measures had a great impact on concentrations of nitrogen dioxide (NO_2) and particulate matter with an aerodynamic diameter lower than 2.5 micrometers (PM2.5)[9]. To confirm this achievement, the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) took several space pictures and realized that the concentration of NO_2 in the atmosphere was reduced by 30%, which can be notable in Figure 2[10].

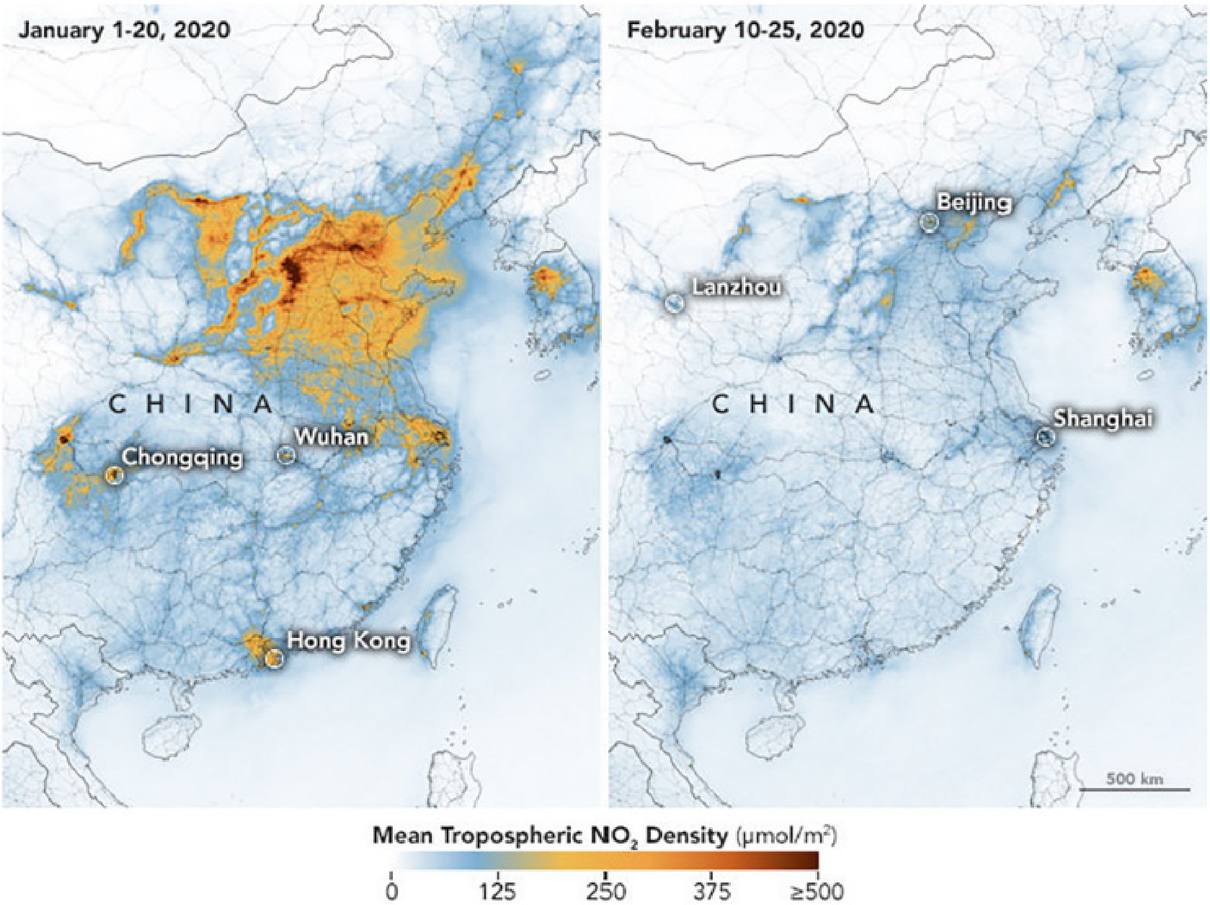

Figure 2. NO_2 emissions in China before and after lockdown[10].

In Europe, air pollution has dramatically decreased since the 'stay at home' measure was applied, leading factories and other economic services stopped their activities. The environmental impact was not only on-air quality but also on environmental noise and on the amount of waste on the streets and beaches[10]. Regarding the NO_2 concentration, it is also possible to observe in Figure 3 its impact on the atmosphere.

As it happened in Europe and Asia (China), the same phenomenon happened all around the world.

The objective of this study was to identify the impact of the COVID-19 virus in the NO_2, CO, and PMx air concentrations worldwide.

Methods

For the development of a solid and consistent knowledge base, the structuring of a revision of existing knowledge, alluding to the subject under study, becomes crucial. The objective of the literature search was to identify the impact of COVID-19 on the environment, especially in air quality. It was used the PRISMA methodology with the instructions elaborated by Liberati *et al.*[11]. The inclusion criteria were: a) articles published between 2019 and 2020; b) articles published in the English language; c) open accessed articles; d) directly related to the pandemic. The selected keywords were COVID, corona, air pollution, and impact. Those were applied in three

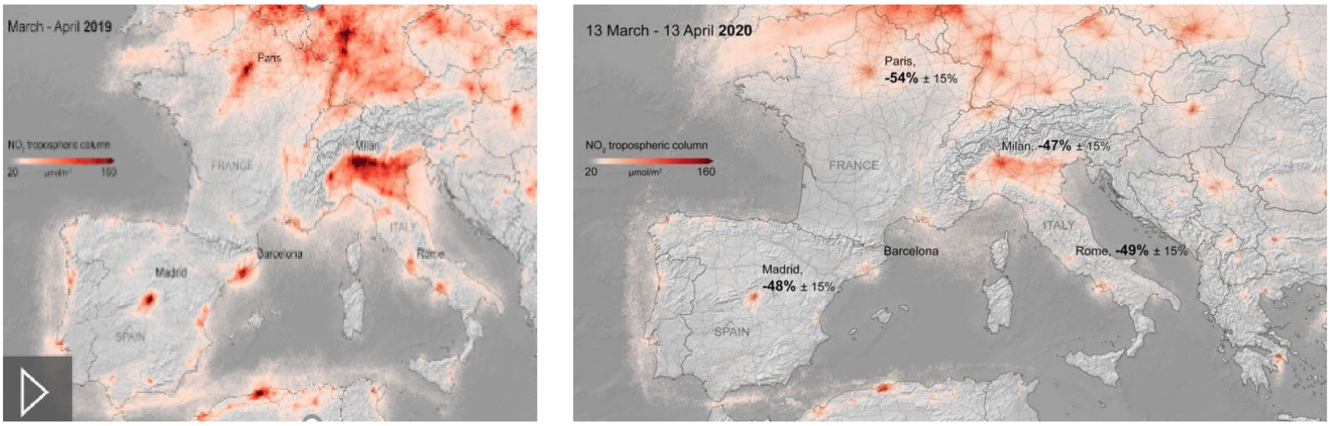

Figure 3. NO_2 emissions in Europe before and after lockdown[10].

different search platforms – Web of Science, Scopus, and PubMed – using the same poll: COVID* OR Corona AND Air pollut* OR Air quality AND Impact. In the first run and without applying any inclusion criteria it was found 96 articles in Web of Science, two in Scopus, and eight in PubMed. Applying the selected criteria and erasing the overlapping articles the final number were four in Web of Science, zero in Scopus, and four in PubMed (*cf.* Table 1).

Table 1. List of articles after PRISMA method' application

Ref.	Title	Country	Pollutants
7	The dramatic impact of Coronavirus outbreak on air quality: has it saved as much as it has killed so far?	Italy	n/a
8	Impact of the COVID-19 event on air quality in Central China	China	$PM_{2.5}$, PM_{10}, SO_2, CO, NO_2, O_3
12	The impact of COVID-19 partial lockdown on the air quality of the city of Rio de Janeiro, Brazil	Brazil	PM_{10}, NO_2, CO, O_3
13	Assessing air quality changes in large cities during COVID-19 lockdowns: the impacts of traffic-free urban conditions in Almaty, Kazakhstan	Kazakhstan	$PM_{2.5}$, NO_2, SO_2, CO, O_3
14	COVID-19 pandemic: impacts on the air quality during the partial lockdown in São Paulo state, Brazil	Brazil	$PM_{2.5}$, PM_{10}, SO_2, CO, NO, NO_2, O_3
9	Indirect effects of COVID-19 on the environment	China, USA, Italy, Spain	$PM_{2.5}$, NO_2
15	Searching for SARS-COV-2 on particulate matter: a possible early indicator of COVID-19 epidemic recurrence	China	PM, NO_2, O_3

Results

The lockdown that took place in China in January 2020 led to the closure of coal-fired power plants and other industrial facilities. This contributed to a decrease of 36% coal consumption at power plants, 15% rates on main steel production, 23% utilization rate of coking plants, 34% utilization of oil refinery capacity, 10% global passenger aviation volume, and an overall of a decrease of 15-40% output across key industrial sectors[8]. Not only the consumption and the production had decreased, but also the air pollutant concentrations, namely $PM_{2.5}$, PM_{10}, carbon monoxide (CO), and nitrogen dioxide (NO_2) concentrations in the air[8]. Figure 4 shows the average concentration of $PM_{2.5}$ and PM_{10} in 2017-2019 and 2020 for each Chinese city: Wuhan, Jingmen, and Enshi. It is possible to observe that the $PM_{2.5}$ concentrations ranged between 17-198, 20-298, and 22-248 $\mu g.m^{-3}$ and averaged 88.8, 115, and 77.1 µg.m^{-3}, respectively. Moreover, and during January of 2020, these concentrations were lower, ranging between 12-108, 26-146, and 15-70 µg.m^{-3} with averages of 59.6, 87.8, and 36.8 µg.m^{-3}, respectively. This means a loss of 33%, 24%, and 52% in pollutant concentration comparing with the years of 2017 to 2019 in the same period. The same phenomenon repeated itself in February, in the same studied cities, in 2017-2019 $PM_{2.5}$ concentrations ranged between 16-165, 24-179, and 12-116 µg.m^{-3} and averaged 67.9, 82.1, and 51.5 µg.m^{-3}, respectively. Those during February 2020 ranged from 9-97, 12-139, and 12-92 µg.m^{-3} and have averaged 38.0, 57.1, and 43.4 µg.m^{-3} each. This translated in an average decrease of 30% in $PM_{2.5}$ concentration[8].

Concerning about PM_{10} concentrations, in January 2017-2019 concentrations ranged between 14-201, 15-251 and 26-292 µg.m^{-3} and averaged 99.6, 110.3 and 101.1 µg.m^{-3}, respectively. In January 2020 the same concentration ranged from 19-135, 10-128, and 21-114 µg.m^{-3}, with averages of 69.9, 73.7, and 50.7 µg.m^{-3}, which were 30%, 33%, and 50% lower than those during January 2017-2019[8]. In February, 2017-2019, the PM_{10} concentration ranged between 13-211, 29-218 and 24-150 µg.m^{-3} and averaged 88.2, 105.0 and 69.6 µg.m^{-3} in the cities in study. These values during February 2020 ranged from 12-103, 13-122, and 21-101 µg.m^{-3}, with averages of 46.0, 54.2, and 52.1 µg.m^{-3}, respectively, which were 48%, 48%, and 25% lower than those during February 2017-2019[8].

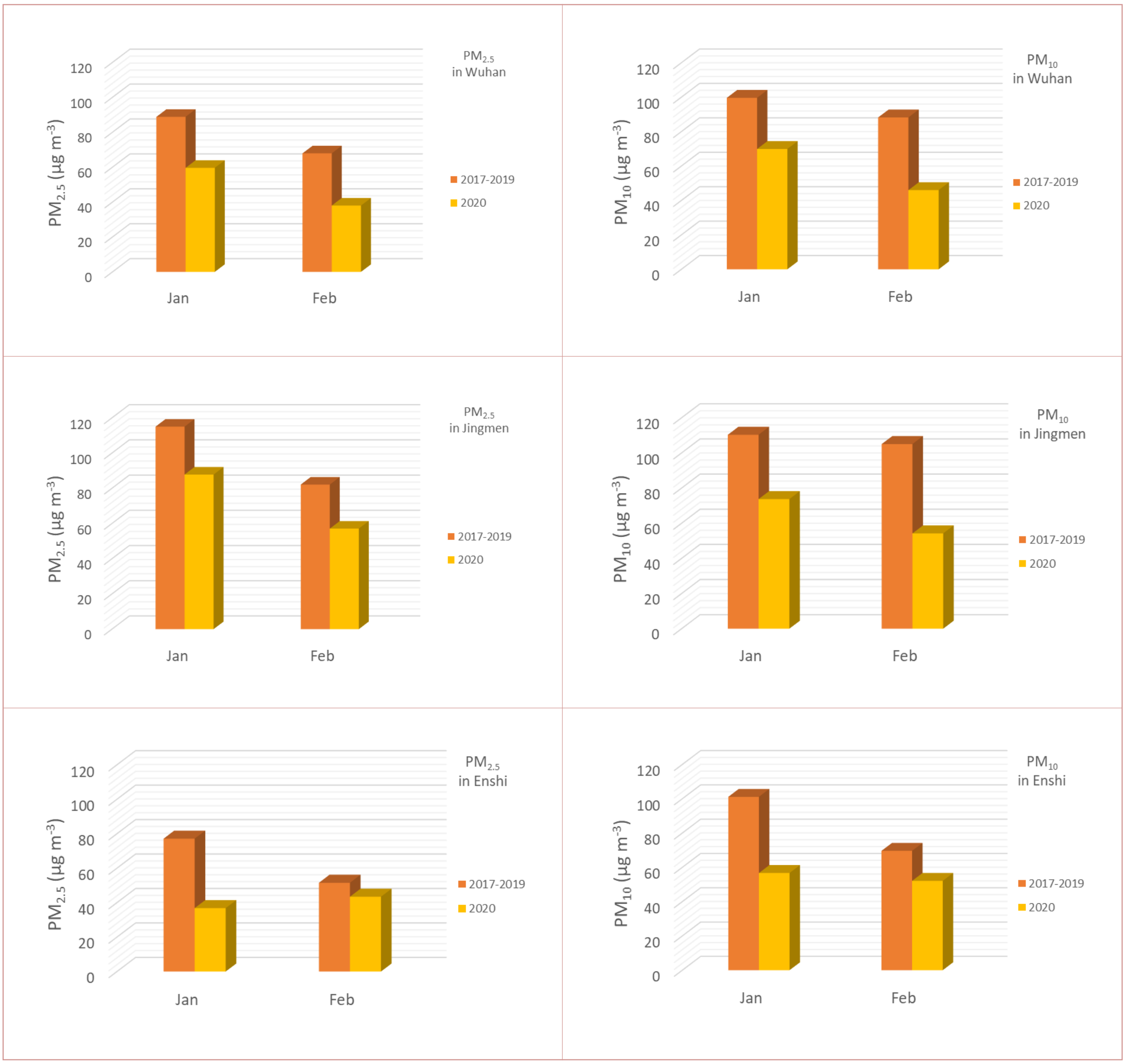

Figure 4. $PM_{2.5}$ and PM_{10} concentrations in Wuhan, Jingmen, and Enshi.

In Wuhan, Jingmen, and Enshi, during January 2017-2019, the CO concentrations ranged between 0.48-1.76, 0.56-1.92, and 0.48-1.92 ppm and averaged 1.03, 1.04 and, 0.99 ppm, respectively. During January 2020 ranged from 0.40-1.28, 0.48-1.12, and 0.32-0.96 ppm, with averages of 0.79, 0.78, and 0.62 ppm, respectively. This represented a decrease of 16.2%, 25.0%, and 37.6% than in the same period of 2017-2019[8]. In February 2017-2019, the values registered ranged between 0.32-1.36, 0.56-.12 and 0.32-1.12 ppm, and averaged 0.88, 0.85 and 0.76 ppm, respectively. During February 2020 ranged from 0.48-1.04, 0.32-0.80 and 0.24-0.64 ppm and averaged 0.73, 0.58 and 0.49 ppm, respectively, representing a decrease of 16%, 32% and 36%[8].

Considering NO_2 concentrations during January 2017-2019, it varied between 8.28-48.7, 6.82-54.1, and 6.33-35.1 ppb and averaged 25.7, 22.9, and 15.2 ppb for Wuhan, Jingmen, and Enshi. NO_2 concentrations during January 2020 ranged from 4.87-37.0, 4.87-30.2, and 2.92-17.0 ppb and averaged 17.9, 17.9, and 14.1 ppb, respectively, which were 30.3%, 38.5%, and 38.1% lower than those during January 2017-2019[8]. In February 2017-2019, the concentrations of these pollutants ranged between 6.33-50.2, 6.34-35.1, and 4.87-21.4 ppb and averaged 30.0, 16.8, and 10.6 ppb, respectively. Those during February 2020 ranged from 4.87-17.5, 2.92-12.7, and 1.46-6.82 ppb, with averages of 10.41, 6.01 and 3.68 ppb, respectively, which were 55%, 64%, and 65% lower than that of during February 2017-2019[8].

Table 2. CO and NO_2 concentrations in Wuhan Jigmen, and Enshi (China)

	2017-2019		**2020**	
	January	**February**	**January**	**February**
Wuhan				
CO (ppm)	1.03	0.88	0.79	0.73
NO_2 (ppb)	25.7	30.0	17.9	10.41
Jingmen				
CO (ppm)	1.04	0.85	0.78	0.58
NO_2 (ppb)	22.9	16.8	17.9	6.01
Enshi				
CO (ppm)	0.99	0.76	0.62	0.49
NO_2 (ppb)	15.2	10.6	14.1	3.68

Table adapted from Xu et al.[8]

Dantas *et al.*[12] developed a study in Brazil assessing the concentrations of PM_{10}, CO, and NO_2 in three Brazilian cities: Irajá, Bangu, and Tijuca. PM_{10} had increased in Irajá and Tijuca (10.7% and 11%, respectively). In Bangu, the concentrations of PM_{10} were lower in the third week in comparison to the second. However, on the 23rd of March when the partial lockdown was implemented it was noticed a visible reduction of PM_{10} and NO_2 in all the stations. PM_{10} concentrations in 2020 varied, in average, 19.5% higher and 28.7% lower than on 2019 for Irajá, Bangu, respectively[12].

NO_2 concentrations in the third week of lockdown were 28.8% higher in Irajá and 1.8% lower in Bangu. Median values were lower in 2020 with 32.9% and 24.1% in Irajá and Bangu, respectively[12]. For CO, values were 15.2% lower and 12% higher in Bangu and Tijuca, respectively. For this pollutant, the concentration level was also lower in 2020 with values of 37.0% and 43.6% in Bangu and Tijuca[12]. Zone levels increased in the cities in the study, during the third week in comparison with the two reference weeks by 31.1, 22.5, and 63.0% for Irajá, Bangu, and Tijuca, in the same order[12].

Table 3 shows the mean concentration and relative change of CO, PM_{10}, $PM_{2.5}$, and NO_2 in São Paulo, Brazil, in two different periods: yearly monthly mean 2015-2019 and 2020. In São Paulo, another Brazilian city, São Paulo State Environmental Agency showed that favorable conditions to pollutant dispersion were found before partial lockdown: February 25-March 23. In the industrial area, it was observed low levels of variation when compared to the five-year monthly mean. Nevertheless, it is important to keep in mind that the factories in Brazil were not obliged to close. In the urban area, it was observed significant air quality improvements considering decreases in air pollutants monitored in areas highly influenced by vehicle traffic (Urban Road I, Urban Road II and City Center)[14]. Extreme reductions on NO (–48.6%, –77.3% and – 72.7% in Urban Road I, Urban Road II and City Center, respectively), NO^2 (–30.1%, –54.3% and –

46.5% in Urban Road I, Urban Road II and City Center, respectively) and CO (–36.1%, –53.1% and –64.8% in Urban Road I, Urban Road II and City Center, respectively) concentrations were observed in the urban area during partial lockdown compared to the five-year monthly mean[14]. This study also showed a reduction of 9.8% in $PM_{2.5}$. By contrast, O_3 experienced an increase of 30% in urban areas highly influenced by vehicle traffic.

Table 3. Mean concentration and relative change of: CO, PM_{10}, $PM_{2.5}$ and NO_2 in São Paulo, Brazil (adapted from Nakada and Urban)[14]

Type of station/Air pollutant	Five year monthly mean (2015/2019)			Relative change (%) (2020)*
	February	March	April	
Industrial				
PM_{10} (µg m³)	24.1	24.2	26.1	-12.7
NO_2 (µg m³)	28.0	28.2	31.4	-5.6
Urban Road I				
CO (ppm)	0.7	0.7	0.6	-36.1
PM_{10} (µg m³)	26.2	25.5	30.4	-22.8
$PM_{2.5}$(µg m³)	14.9	15.3	17.8	-29.8
NO_2 (µg m³)	51.3	50.5	53.0	-30.1
Urban Road II				
CO (ppm)	0.5	0.5	0.6	-53.1
NO_2 (µg m³)	33.3	35.7	37.0	-54.3
City Center				
PM_{10} (µg m³)	21.5	21.8	-	-
$PM_{2.5}$ (µg m³)	-	-	-	-
NO_2 (µg m³)	33.1	34.8	35.9	-46.5

* = A: Four-week during partial lockdown vs Five-year monthly mean for April.

According to Kerimray, concentrations of $PM_{2.5}$, NO_2, and CO were compared between the periods before and during the lockdown in Almaty, Kazakhstan[13]. In Almaty, Kazakhstan, and during the lockdown measures $PM_{2.5}$ concentrations during the lockdown event were 38 $\mu g.m^{-3}$, 40 $\mu g.m^{-3}$, and 31 $\mu g.m^{-3}$ in 2018, 2019, and 2020, respectively, which indicates an average reduction of 21% in 2020[13]. There were also some reductions in NO_2 and CO by 49%[13].

Discussion

As a general trend in the majority of the world countries, concentrations of the principal pollutants showed a decrease in the first days of the lockdown[12], in consequence of the powerplant and coal factories closing and due to the massive reduction on the traffic flux in the major cities[7-9,12-14].

On 23rd of March when the partial lockdown was implemented it was observed a perceptible reduction of PM_{10} and NO_2 in all the stations in the study on Brazil, not only because of a decrease of approximately 80% in the traffic but also could be explained with the meteorological parameters and with the reduce/suspending of some activities, construction works and industrial emissions[12].

Regarding China, the pollutant with the major decrease recorded was NO_2. The decrease of the concentrations of atmospheric pollutants in the three cities in the study (Wuhan, Jingmen, and Enshi), in January, can be explained by the decrease in construction dust and industrial production emissions during the Lunar New Year holidays, and in February and March because of the COVID-19 epidemic prevention and control actions undertaken by the government, with restricted industrial production and transportation activities, which led to a reduction in emissions from factories and vehicles[8].

The containment measures implemented by the different governments to control COVID-19 had an impact on the lifestyle of the people and consequentially had a positive impact on outdoor air quality, observed not only in China but also in Italy, Spain, France, and other areas of the world[9].

Conclusion

Following the pandemic of COVID-19, human activity decreased substantially, consequently causing a significant reduction in industrial activity, energy production, road traffic, and air traffic. This situation came to be accentuated with countries promoting lockdown as a way of controlling the pandemic, which led to the reduction of atmospheric emissions.

In China in January 2020, there were significant reductions in the concentration of primary pollutants, such as CO, NO_2, and particulate matter ($PM_{2.5}$ and PM_{10}), when compared with the average values of the same month between 2017 and 2019. In February, after the determination of the mandatory lockdown, this difference was accentuated. After an initial phase in which the cessation of most activities was not promoted which contributed to a slight increase in the concentration of pollutants, the phenomenon previously seen in China ended up replicating itself also in Brazil, where there were reductions of 12.7% to PM_{10} and 5.6% for NO_2, in an industrial context and having as reference the average values of February, March, and April, between 2015 and 2019. In areas associated with urban traffic, the differences became even more significant for the CO (-53.1%), PM_{10} (-22.8%), $PM_{2.5}$ (-29.8%) and NO_2 (-54.3%). Similar results were observed all around the world.

These results make it possible to conclude that the pollutants under analysis result essentially from human activities and from industrial activities and road traffic.

It is now important when reopening borders and resuming economic activities, to make efforts to ensure that there is no further increase in the concentration of air pollutants and that it is imperative to continue to promote environmental assessments of air quality.

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