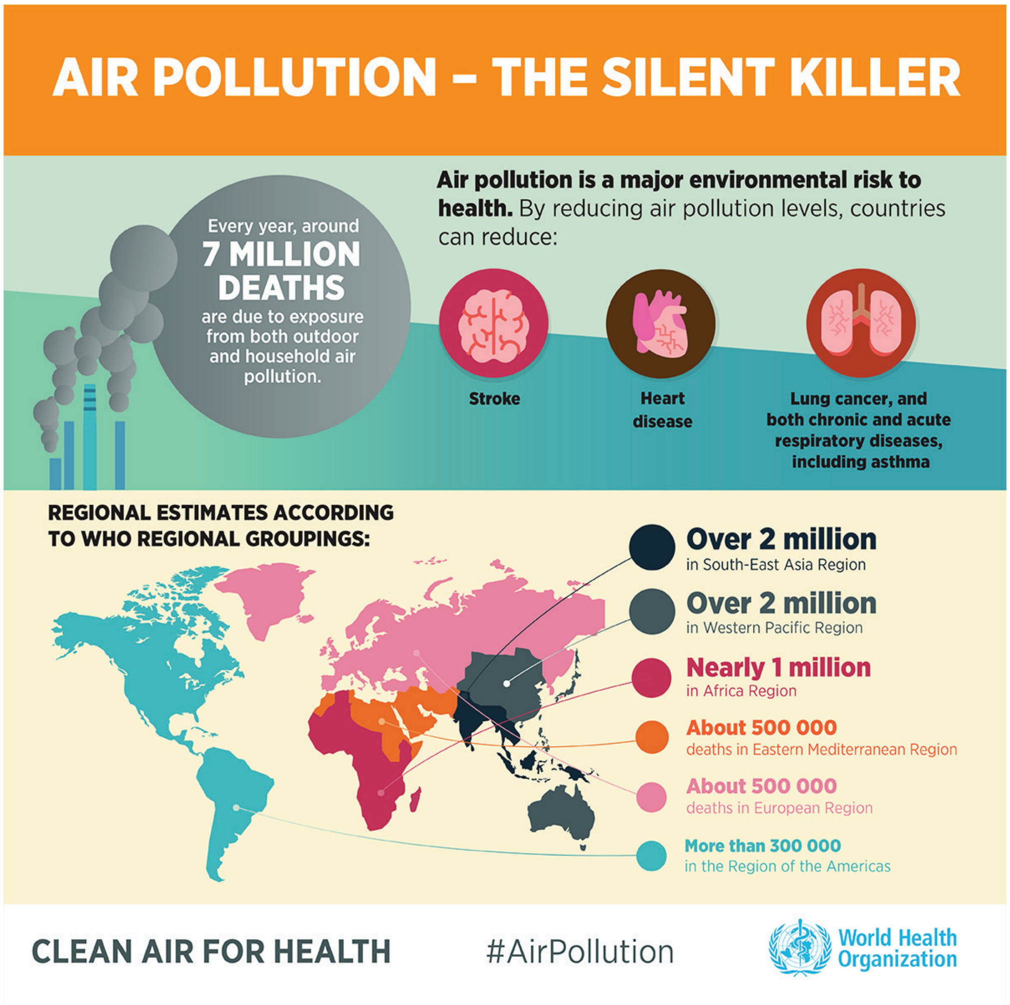
Effects of the quarantines and activity restrictions related to the coronavirus disease (COVID-19) on air quality in Latin America's cities

July 2020

Air pollution represents a major environmental health hazard. According to the World Health Organization (WHO), it is responsible for 300,000 deaths every year in the Americas, and **9 in every 10** people are breathing polluted air at this very moment.

The air pollutants that are most harmful to human and environmental health are coarse particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2).



Source: World Health Organization (WHO).

Although the pollutants PM_{10}, $PM_{2.5}$, NO_2 and SO_2 can be generated by natural processes (for example dust, sand, volcanic ash, and fog), they are mainly emitted and are thus suspended in the air, as a result of human activities, in conjunction with technology and the energy matrix. The latter affect the pollution generated by transport; the burning of fossil fuels; the operations of industries, foundries, heating and boilers; and certain types of stove. The concentrations of these pollutants in city air are then determined by the environmental conditions prevailing in each case.[1] As multiple factors are in play, it is impossible to attribute any reduction in concentrations exclusively to the activity restrictions and quarantines imposed to deal with the current COVID-19 pandemic.

The measures adopted by the region's national or local governments to limit the spread of the COVID-19 pandemic include quarantines, lockdown orders and the reduction or cessation of economic activities, which have impacted production levels and human mobility. As there is also anecdotal evidence that air quality has improved, the statistical data are reviewed to determine whether the measures deployed have in fact contributed to better air quality in Latin American cities.

This document presents the results of a statistical investigation into the concentrations of three key pollutants,[2] $PM_{2.5}$, $NO_{2.}$ and SO_2, in selected cities[3] of the region that are home to about 14% of Latin America's urban population: Bogotá, Lima, Mexico City, Monterrey (Mexico), Quito, Santiago and São Paulo (Brazil). The observed pollution concentrations are presented graphically, contrasting the levels recorded during the first few months of 2019 with those of 2020.

The data show that ambient NO_2 and SO_2 concentrations in Latin American cities have decreased during the quarantines —mainly at the beginning—, while $PM_{2.5}$ levels have fluctuated both before and during the period of restrictions. To provide a benchmark, statistical data are also presented for three cities in Europe and two in China, where pollutant concentrations have also declined in 2020, albeit starting from different absolute index values than those in Latin America.

The unit of measurement used in this study is the air quality index (AQI), which is based on data obtained from monitoring stations located in the different cities.[4] The graphs for each pollutant use benchmark values to classify air quality levels ("good", "moderate", "unhealthy", "very unhealthy" and "hazardous", among others) according to the standard of the United States Environmental Protection Agency (EPA).

A. Reduction of breathable air pollutants in selected Latin American cities

In general, the absolute levels of the concentration indices of three pollutants studied in Latin American cities have fallen sharply in 2020 relative to the previous year, and they have varied much less through time. The indices also display high levels of heterogeneity, a degree of weekly variability and, in some cases, outlier values.

1 Environmental conditions include air currents and winds; seasonal temperatures; city topography (for example, Santiago is surrounded by mountains, which causes a thermal inversion effect that traps pollutants in the air); precipitation volumes and the degree of humidity. In addition, the existence of barren terrain combined with air currents causes dust to dispersed and remain suspended in the air.

2 See the technical note at the end of this document (box 2), on the sources and health effects of the three pollutants studied.

3 Several capital cities and other large metropolitan areas in Latin America were studied, but only selected cases are presented in this document.

4 The methodological note at the end of this document (box 1) describes both the index and the scale used in this study.

1. Sulfur dioxide (SO_2) pollution abates in the cities studied, particularly in Mexico City and Lima

Sulfur dioxide concentrations have decreased during the quarantine periods in all of the cities studied, except Santiago. This pollutant is emitted mainly from the burning of fossil fuels, particularly in transport and industry.

Figure 1 shows that SO_2 pollution dropped sharply in five of the six cities at the start of the quarantines imposed in March 2020, before flattening out —possibly associated with an increase in activities and less compliance with the restrictions. Santiago displays a different pattern, with SO_2 levels rising until mid-May 2020, before dropping sharply to below those recorded in 2019. In terms of absolute AQI levels, São Paulo, Bogotá and Santiago display lower levels of pollution than the other cities in both years.

Figure 1
Latin America (selected cities): weekly average of maximum daily concentrations of sulfur dioxide (SO_2), March–May 2019 and 2020
(Air Quality Index)

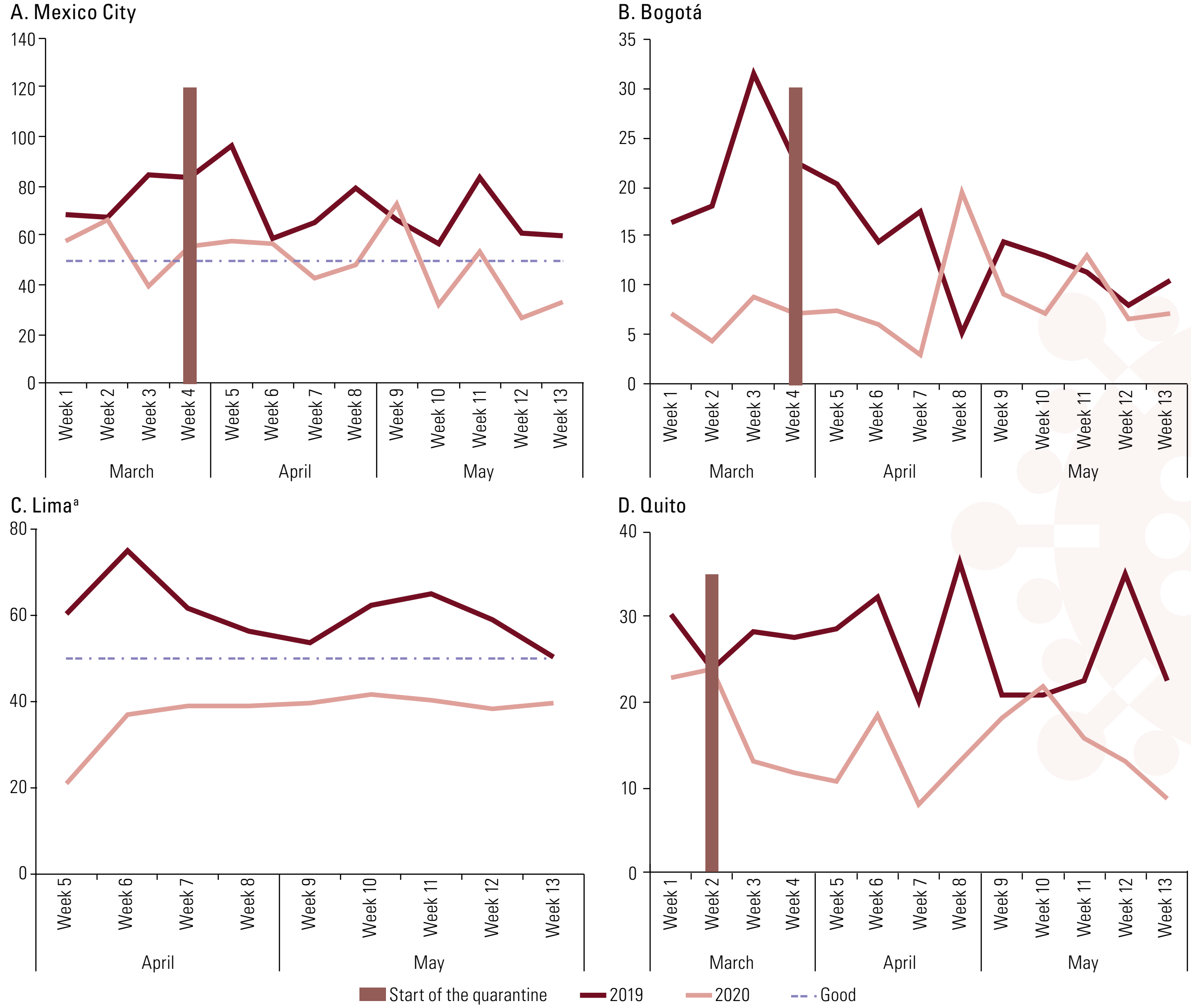
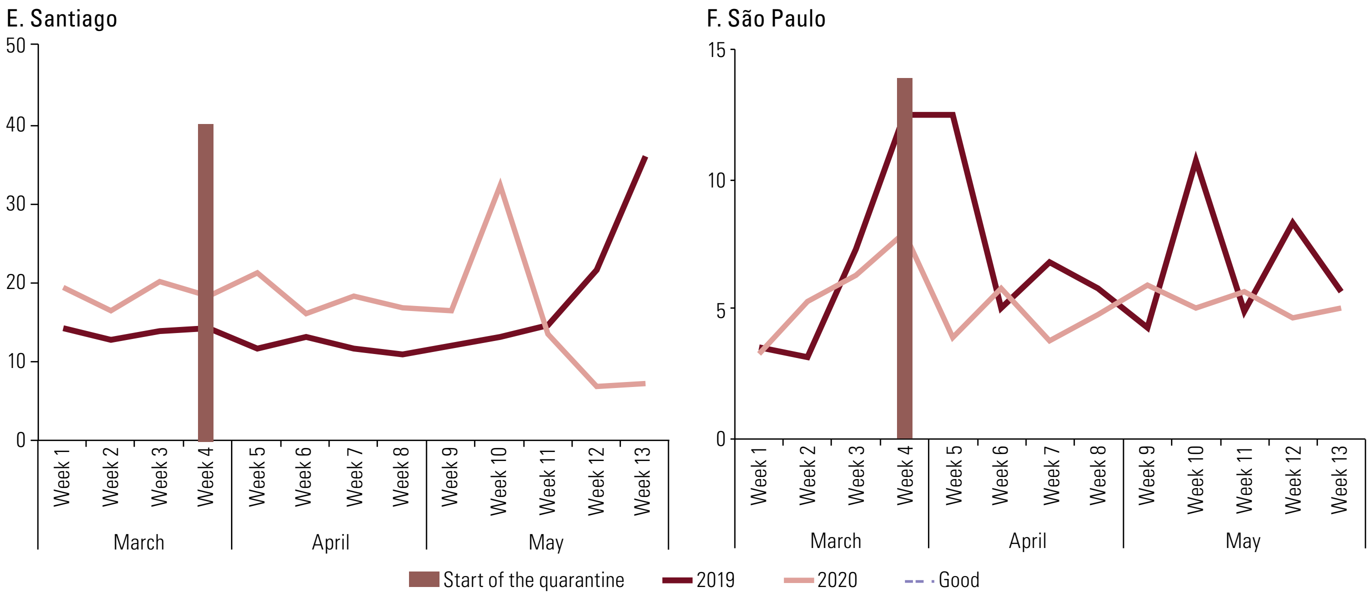


Figure 1 (concluded)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.

[a] The quarantine in Lima started in March 2020.

In Mexico City, a metropolis of 20 million inhabitants,[5] the AQI in terms of SO_2 concentration fell by 35 points from 84 points in March 2019 to 39 in March 2020, coinciding with the declaration of a pandemic by the World Health Organization (WHO) on 11 March 2020.

In Lima, a city of 8.5 million, SO_2 concentration levels also dropped, from 66% of the year-earlier level in the first week of April 2020 to 20% in the last week of May. As a result, air quality in the city of Lima is rated "good" according to the AQI and is not considered harmful to health.

In Santiago, which has a population of 7 million, the AQI has been at levels within the "good" range on the dates studied. Until the third week of May 2020, SO_2 concentrations were higher than their corresponding 2019 levels, after which the 2020 figures are lower than those of a year earlier. Moreover, SO_2 concentrations are well below those recorded in Lima and Quito and equivalent to a third of the level in Mexico City.

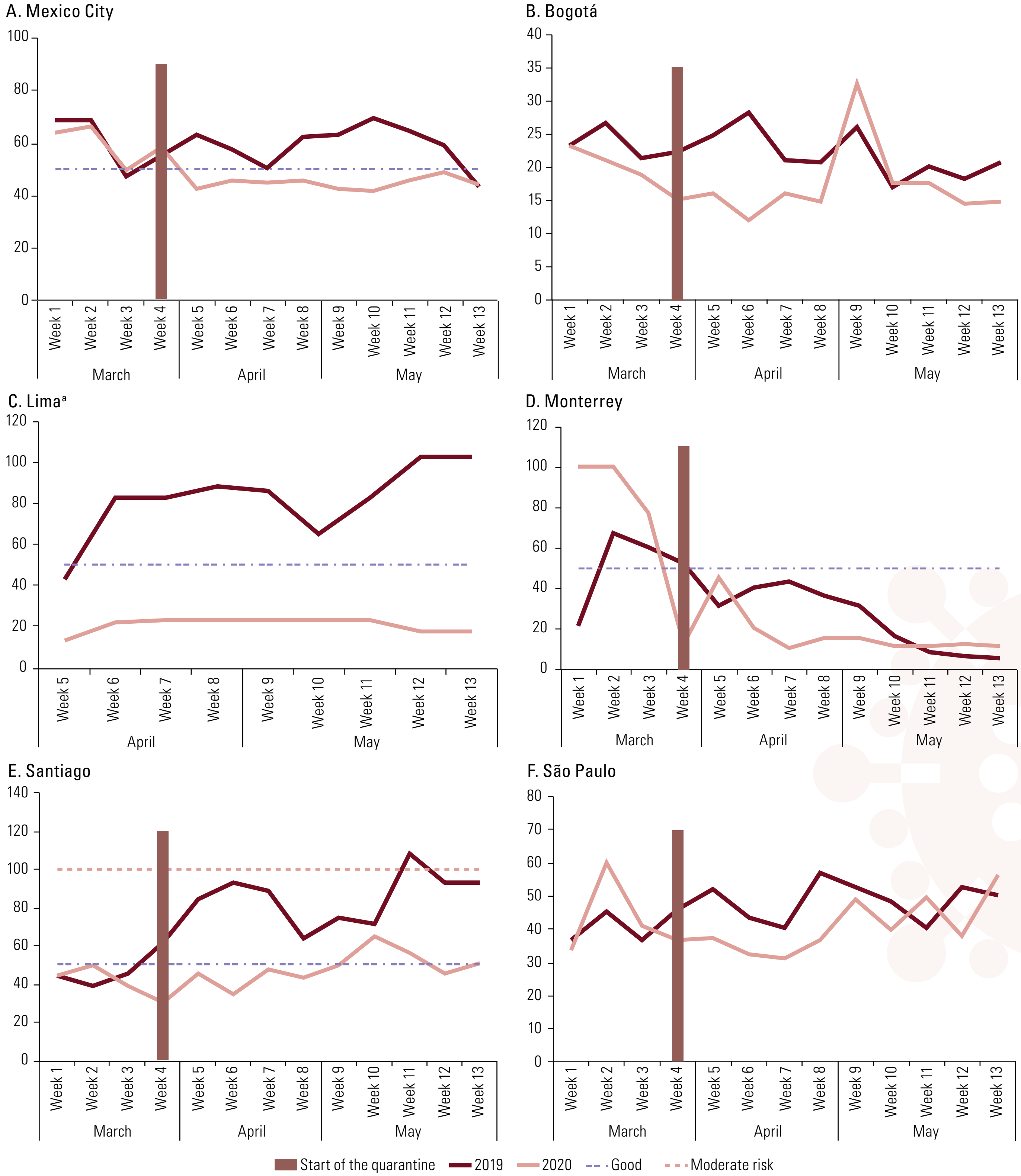
2. Nitrogen dioxide (NO_2) pollution decreases in the cities studied, especially in Lima and Santiago

The reduction in NO_2 concentrations is evident in the cities studied. This is a pollutant emitted mainly by industries, thermoelectric power plants and automobiles, particularly those that run on diesel.

Figure 2 shows the sharp reduction in NO_2 concentrations between 2019 and 2020 in the six cities, particularly in Santiago and Lima. A slight increase in pollution can be discerned in the later weeks in Bogotá, São Paulo and Monterrey.

[5] Data from the Latin American and Caribbean Demographic Centre (CELADE)-Population Division of ECLAC, 2019.

Figure 2
Latin America (selected cities): weekly average of maximum daily concentrations of nitrogen dioxide (NO_2), March–May 2019 and 2020
(Air Quality Index)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.
[a] The quarantine in Lima started in March 2020.

In Lima, NO_2 concentrations in 2020 have been lower than in the previous year —50% below the year-earlier level at the start of the period and eventually 80% below. In 2020, Lima's NO_2 concentrations were in the "good" air quality range, unlike the situation in 2019.

In São Paulo which has a population of 20 million, NO_2 concentrations were more than 30% lower in mid-March 2020 than the year-earlier period; and from then until the first week of May, concentration levels remained lower than in 2019, staying within the "good" air-quality range.

In Santiago, NO_2 concentrations fell sharply as from the third week of March 2020, to reach 66% of the year-earlier level in early April. As a result, Santiago's air quality was in the index range classified as "good", except during part of May 2020.

Although Monterrey displayed extremely high NO_2 concentrations in early 2020 (above their 2019 levels), by late April 2020, the index was trending steadily down; and since then it has remained within the air quality range rated as "good".

3. Air pollution from fine particulate matter $PM_{2.5}$ is also lower, particularly in Bogotá and Quito

Fine particulate matter is generated as a non-specific combination of solids and gases, which inflame the upper and lower airways. Although mobility and fossil combustion both decreased in the period under study, it is likely that some suspension of dust and particles from burning and heating persisted (especially in South American cities that enter the southern autumn in March and winter in June).

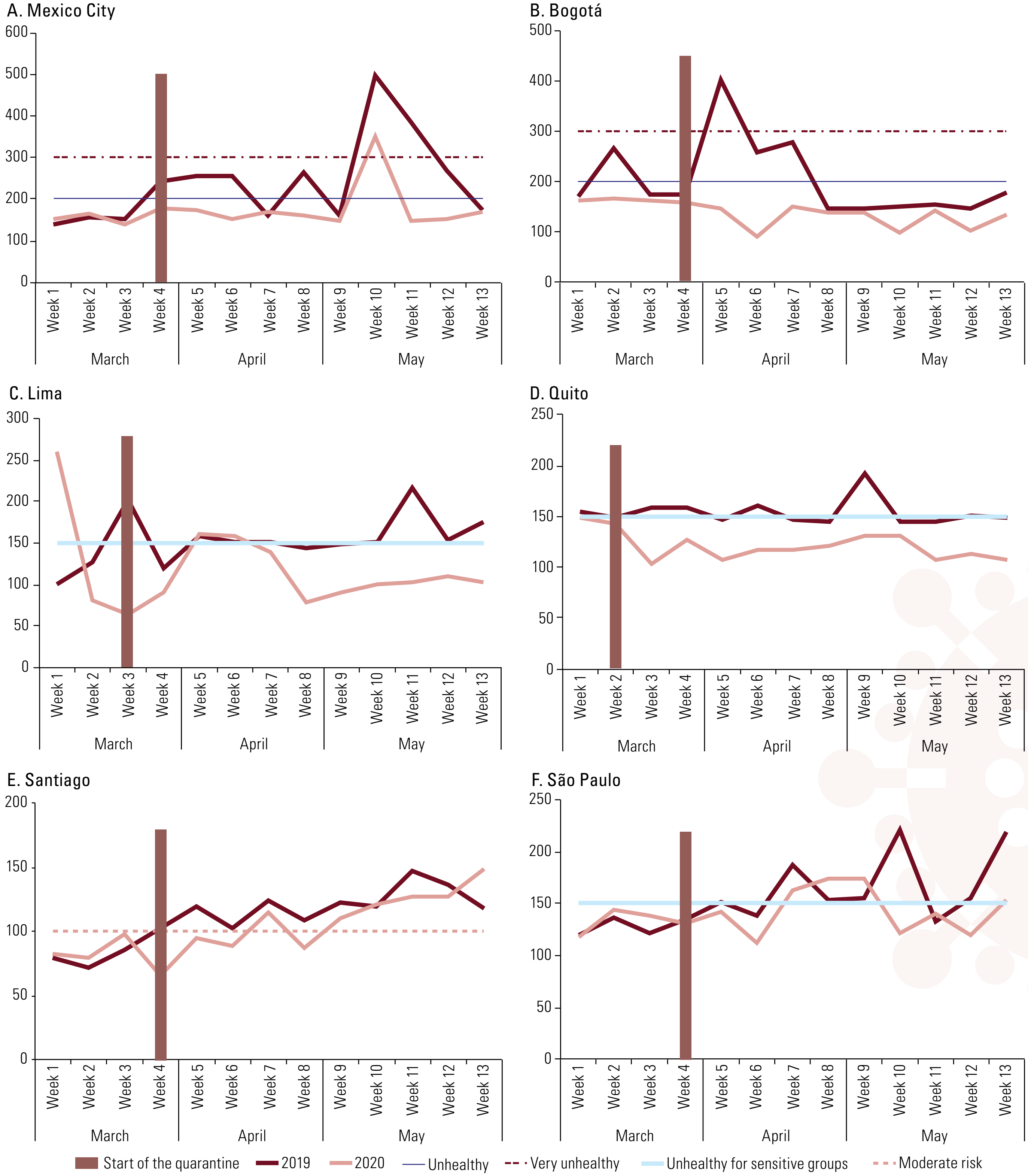
Concentrations of $PM_{2.5}$ declined during the 2020 quarantine but remained somewhat volatile; and AQI levels have been in the "moderate", "very unhealthy" and "unhealthy" ranges in both years, particularly in Mexico City and Bogotá. Santiago and São Paulo have seen an upward trend in both 2019 and 2020.

In Santiago, where these rising trends have taken it beyond the "moderate" pollution range of the AQI, $PM_{2.5}$ concentrations fell in 2020 compared to their year-earlier levels, but the trend reversed at the end of May. In Mexico City, $PM_{2.5}$ levels in 2020 were lower as from the third week of March, before rising sharply in May in both years, into the "unhealthy" and "very unhealthy" ranges.

In Bogotá, a city of 7.2 million, $PM_{2.5}$ concentrations decreased by up to 64%, with the AQI dropping from 403 points on in the first week of April 2019 (within the "very unhealthy" range) to 143 a year later. The trend in 2020 has also been downwards, in contrast to the sharp increases in air pollution levels (into the "unhealthy" range) during the same period a year earlier.

In Quito, $PM_{2.5}$ concentrations during the first week of March were very similar in both 2019 and 2020 (155 and 150 points, respectively). From the declaration of lockdown on March 12, 2020 until late May 2020, the $PM_{2.5}$ concentration declined continuously and substantially, and is now below the "unhealthy for sensitive groups" range, with reductions of between 31% and 10% relative to the year-earlier period.

Figure 3
Latin America (selected cities): weekly average of maximum daily concentrations of fine particulate matter ($PM_{2.5}$), March-May 2019 and 2020
(Air Quality Index)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.

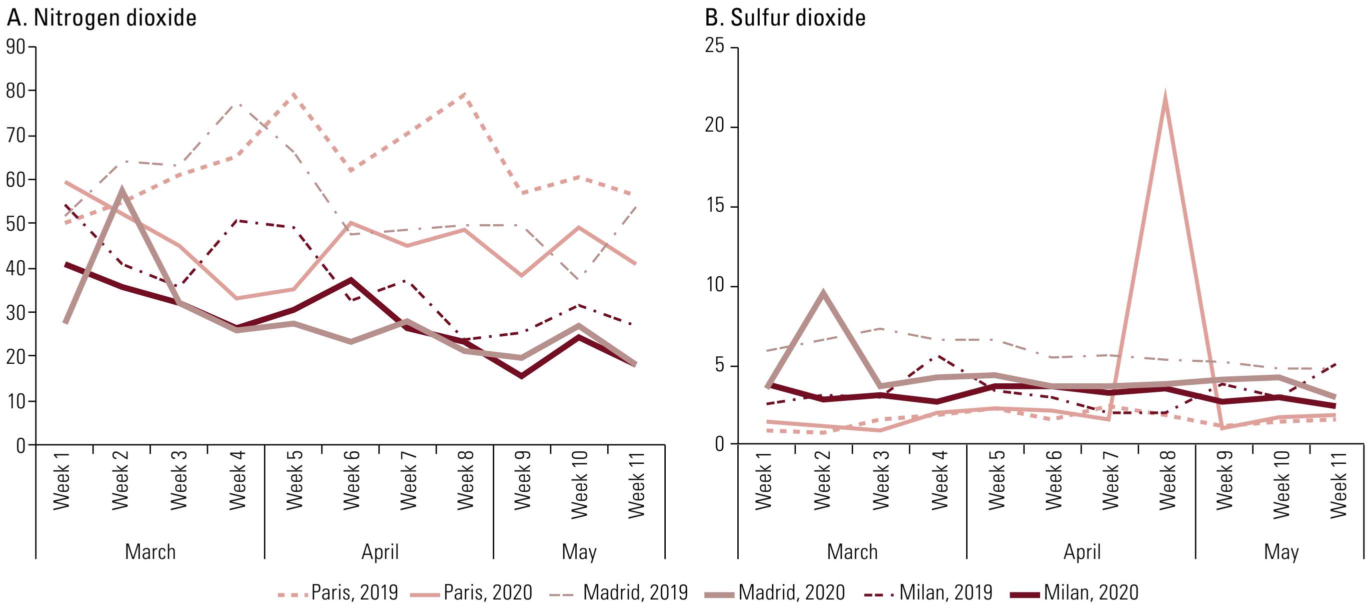
B. Abatement of air pollution in European and Chinese cities

1. European cities: Madrid, Milan and Paris

Madrid, Milan and Paris report NO_2 and SO_2 concentrations within the range considered "good", with absolute index levels that are lower than those recorded in Latin American cities. In the case of $PM_{2.5}$, however, the absolute index levels observed in European cities are similar to those of several Latin American ones and only lower than those recorded in Mexico City and the very high levels recorded in certain other cities in the region.

In addition, during the analysis period (March–May 2020 compared to the same months in 2019), NO_2 concentrations in Madrid and Paris decreased sharply, particularly in March (see figure 4A). The NO_2 concentration in Milan is also trending down, although less steeply. In the case of SO_2 (see figure 4B), both the absolute levels of the AQI and the relative reductions observed are lower in Madrid, Milan and Paris than in the Latin American cities considered. Excluding the atypical observation in Paris (in the fourth week of April), the largest reduction in the AQI occurred in Milan, where it dropped by two points to level 3 in late March 2020.

Figure 4
Europe (selected cities): weekly average of maximum daily concentrations of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), March–May 2019 and 2020
(Air Quality Index)

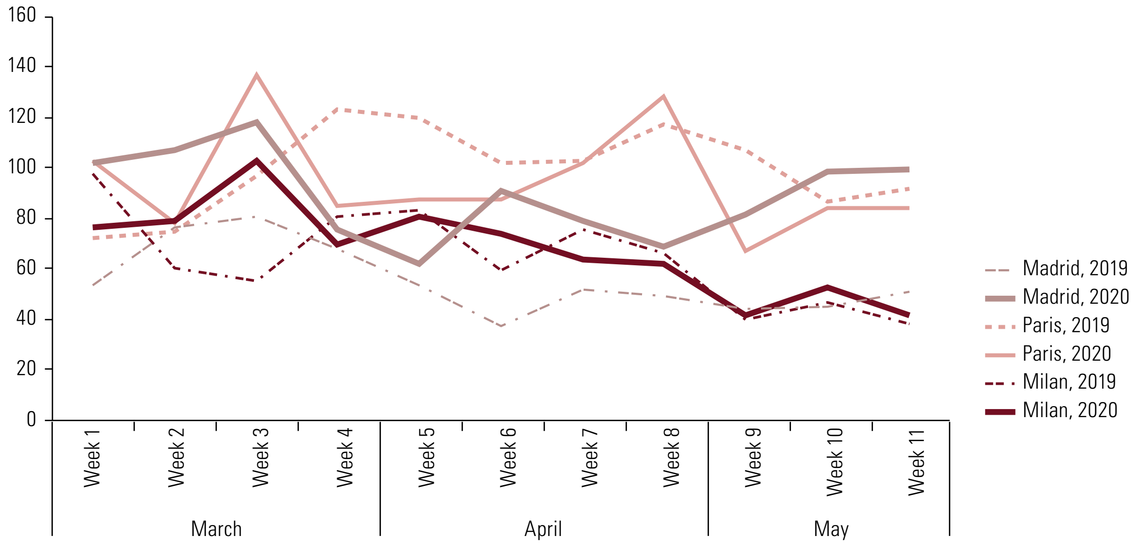


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.
Note: The quarantines began on the following dates: on 15 March 2020 in Madrid; on 10 March 2020 in Milan; on 17 March 2020 in Paris.

In the case of $PM_{2.5}$ (see figure 5), concentrations in 2020 were above the 2019 levels in Madrid, even though that city saw a significant decrease in traffic volumes[6] and also endured more stringent lockdown measures than anywhere else in Europe. In other European cities, such as Milan and Paris, $PM_{2.5}$ indices vary greatly.

6 Gasoline sales have fallen by 83% and diesel sales are down by 61%, reflecting a 75% reduction in traffic volumes within the city's M-30 ring road. See Dirección General de Tráfico (DGT) of Spain, *Evolución del tráfico por el efecto de COVID-19*, 2 April 2020 [online] http://www.dgt.es/Galerias/covid-19/Evolucion-Intensidades-dia-02-04-2020-Periodo-Coronavirus.pdf.

Figure 5
Europe (selected cities): weekly average of maximum daily concentrations of fine particulate matter ($PM_{2.5}$), March–May 2019 and 2020
(Air Quality Index)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.
Note: The quarantines began on the following dates: on 15 March 2020 in Madrid; on 10 March 2020 in Milan; on 17 March 2020 in Paris.

2. Chinese cities: Wuhan and Beijing

As the COVID-19 outbreak occurred in China before reaching Europe and Latin America, pollution levels in Chinese cities have been monitored since January 2020.

Absolute levels of $PM_{2.5}$ in the cities of Wuhan and Beijing are extremely high, reaching the "very unhealthy" to "hazardous" range —above those recorded in Latin American cities. SO_2 and NO_2 concentrations in these two Chinese cities are similar to those recorded in the Latin American ones and are generally in the "good" to "moderate" range.

In both Chinese cities, pollution as measured by the three parameters was generally lower in the 2020 quarantine period than in 2019. $PM_{2.5}$ concentrations decreased in both cities, although more steeply in Wuhan. Beijing also displays reductions in both NO_2 and SO_2 in 2020, whereas Wuhan reported higher NO_2 pollution during the 2020 quarantine period.

Figure 6 shows that $PM_{2.5}$ concentration levels in Wuhan were continuously lower in the first three months of 2020 than in the year-earlier period; but the situation was reversed as from the first week of April 2020, when lockdown ended in both cities. In both Beijing and Wuhan, although pollution levels are very high and attain ranges considered "very unhealthy" to "hazardous", there is evidence of declining trends in $PM_{2.5}$ pollution during the first quarter in both years.

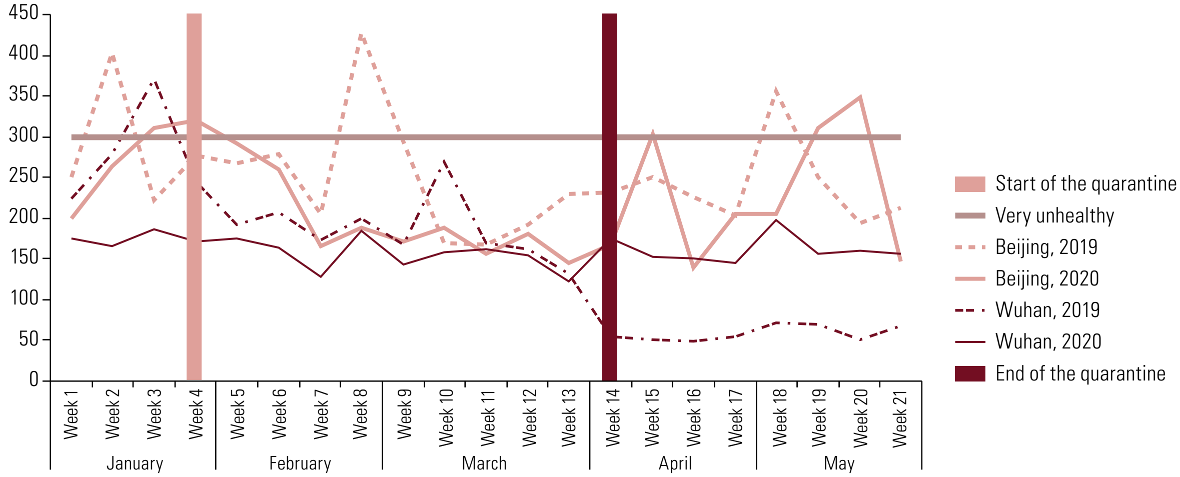
Figure 7 shows that NO_2 concentrations in Beijing were clearly lower in 2020 than in 2019, while Wuhan shows higher levels of pollution in 2020 than in the previous year.

In addition, SO_2 concentrations in Beijing trended down in 2020 relative to a year earlier (except for two weeks). In the city of Wuhan, although SO_2 pollution in 2020 is generally lower than in 2019, no clear comparison can be made between the two years, since the two series fluctuate widely and intersect each other repeatedly.

Figure 6

China (selected cities): weekly average of maximum daily concentrations of fine particulate matter ($PM_{2.5}$), January–May 2019 and 2020

(Air Quality Index)



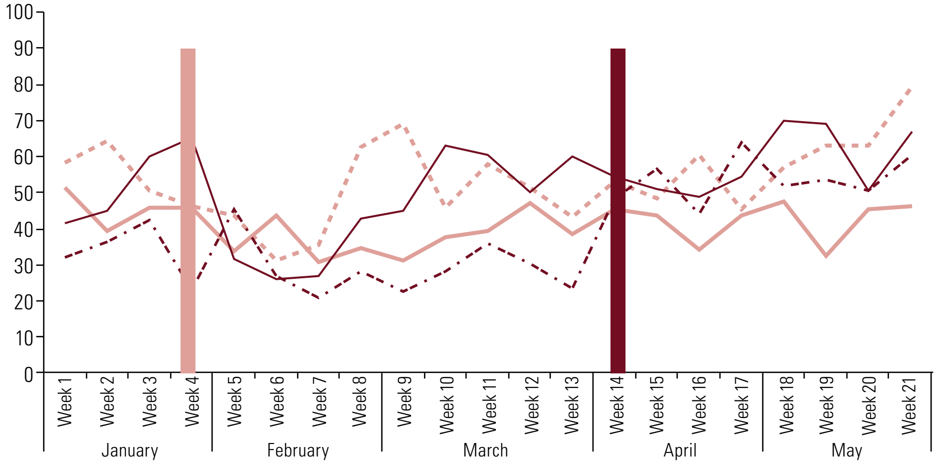
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.

Figure 7

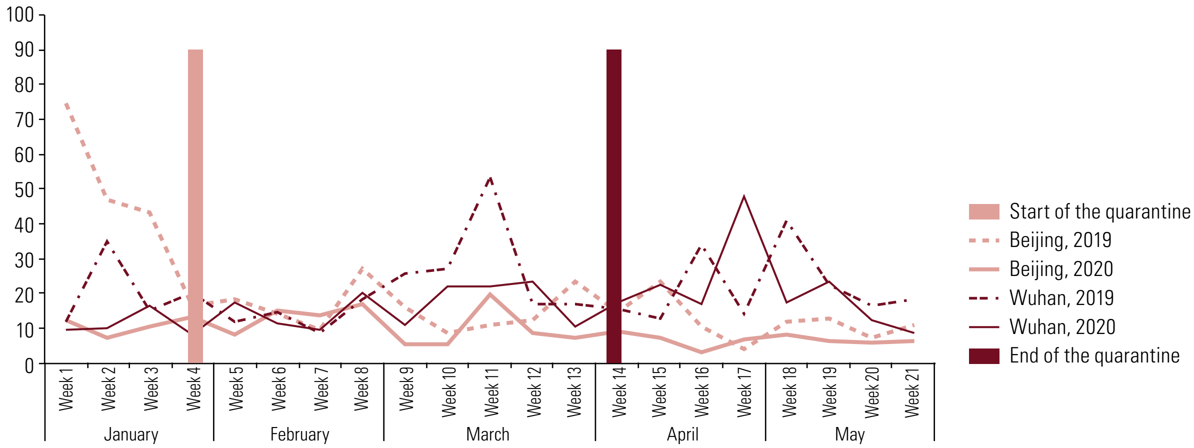
China (selected cities): weekly average of maximum daily concentrations of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), January–May 2019 and 2020

(Air Quality Index)

A. Nitrogen dioxide



B. Sulfur dioxide



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from *The World Air Quality Project* [online] www.aqicn.org.

C. Summary and closing thoughts

The decrease observed in concentrations of the three pollutants in the breathable air of Latin American cities represents an improvement in environmental and human health (less respiratory morbidity and mortality), especially among vulnerable groups.[7]

Specifically, during the 2019/20 analysis period, air quality generally improved in the cities studied (Bogotá, Lima, Mexico City, Monterrey, Quito, Santiago and São Paulo), with the ambient concentrations of all three pollutants ($PM_{2.5}$, NO_2 and SO_2) declining during the 2020 lockdown and quarantine period. City air quality improves the most during the initial quarantine weeks, after which the situation tends to reverse, albeit with some exceptions.

High degrees of heterogeneity and variability are also observed, along with outlier values. Unexpected situations arise in some cities and in certain weeks: for example (i) higher levels of pollution in certain weeks during the quarantine period; and (ii) volatility in pollution levels, with the 2020 and 2019 trend lines intersecting each other, as their values overtake each other week by week.

This can be explained by the persistence of activity levels and circulation in some cities despite the restrictions imposed, combined with the environmental factors that influence how pollutants disperse in each city. The socioeconomic factors that affect movement and activities during the pandemic include structural income inequality, the precarious nature of employment, rising unemployment and the prevalence of a large informal sector. These factors mean that many people are forced to go out to earn their living every day, since financial assistance has not been made available in a timely manner for vulnerable sectors. In contrast, higher-income workers can comply with quarantine measures by teleworking. The media have also reported cases of people engaging in group recreational activities without observing physical distancing measures or using masks.

Once the quarantine and health emergency are over, there could be a significant increase in pollutant emissions and concentrations in the breathable air of the cities.

Accordingly, lower pollutant concentrations and better air quality could prove to be transient phenomena, unless production and consumption patterns, working practices and economic solidarity with the most vulnerable sectors are developed and consolidated. This would contribute both to economic recovery and to an improvement in personal and environmental health, aligned with a new pattern of healthy, inclusive and sustainable development.

Box 1
Methodological note: how air pollutants are measured, and which data source was used

Pollutant concentrations in breathable air are measured by direct observation using instruments located at on-site monitoring stations. Some cities have several stations that measure various pollutants every hour according to local regulations. The data in question are then aggregated into averages, minima and maxima, which are reported to the health and environmental authorities and local governments for the purpose of implementing restriction measures using the management instruments available to them. It is also possible to estimate pollutants using remote sensors.

Data source

The statistical series on which this document is based are processed and presented in the form of air quality indices associated with concentration levels for each pollutant. This index compiles official data from the environmental agencies or authorities in each city, obtained from monitoring stations. A comparison made of concentration levels at local monitoring stations showed levels consistent with those reported by the global compiler. Hence, the World Air Quality Project is used as a source in the study because: (i) it reports parameters, levels and trends that are consistent with those of the on-site monitoring stations located in the cities; (ii) it adds value by transforming the concentration levels into an index with gradients associated with air quality levels ranging (from "good" to "hazardous"), as defined by the United States Environmental Protection Agency (EPA); and (iii) it also provides sufficient data density for various air pollution parameters, harmonized globally. It should be noted that the unit of measurement in this document is the AQI, and not the usual measurement reported by the primary data, namely micrograms per cubic metre (mg/m^3).

7 See World Health Organization (WHO), "Burden of disease due to ambient air pollution", Global Health Observatory (GHO) [online] https://www.who.int/data/gho/indicator-metadata-registry/imr-details/2259.

Box 1 (concluded)

As can be seen in the following table, the AQI is associated with a quality scale aligned with the latest EPA standard, using the Instant-Cast (NowCast) formula described below:

Air quality scale Air quality index	Health implications	Cautionary statement
0–50	Well	Air quality is considered satisfactory and air pollution poses little or no risk.
50-100	Moderate	The air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
100–150	Unhealthy for sensitive groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
150–200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
200–300	Very unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.
300–500	Dangerous	Health Alert: everyone may experience more serious health effects.

Source: The World Air Quality Project "Air Quality Scale" [online] https://waqi.info/.

Why use AQI?

Twenty-four hours averaging is considered an inaccurate way to measure pollution, owing to the dynamic behaviour of the air:

- Pollution levels can be distorted because the air can be completely cleaned in less than 30 minutes. This phenomenon is frequently seen in Beijing with strong northern winds able to bring the $PM_{2.5}$ AQI from more than 300 to less than 50 in less than an hour.
- Air quality can also suddenly worsen. A famous case refers to the Indonesian wildfire causing Singapore smog when winds are heading north, in which case the AQI can go from less than 50 to more than 150 in just one hour.

That is why EPA introduced the NowCast system, which is a conversion formula used to counterbalance the need to average air quality under changing conditions.

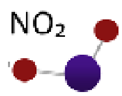
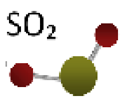
For example, the particulate matter (PM) NowCast is a weighted average of air monitoring data per hour. The PM NowCast is computed from the most recent 12 hours of PM monitoring data, but the NowCast weights the most recent hours of data more heavily than an ordinary 12-hour average when pollutant levels are changing. The NowCast is used in lieu of a 24-hour average PM concentration in the calculation of the AQI until an entire calendar day of hourly concentrations has been monitored.

$$NowCast=\frac{\sum_{i=1}^{N} w^{i-1}c_i}{\sum_{i=1}^{N} w^{i-1}} \quad where\ w=\begin{cases} w^*\ if\ w^*>W_{min} \\ W_{min}\ if\ w^*\leq W_{min} \end{cases} \quad and\ w^*=\frac{C_{min}}{C_{max}} \quad and\ W_{min}={}^{1}\!/_{2} \quad and\ N=12$$

The concept behind NowCast is to compensate the 24-hour averaging that should be used when converting concentrations to AQI. The AQI scale also specifies that each of the levels of health concern (for example, "good", "moderate", or "unhealthy") is valid under a 24-hours exposure.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of The World Air Quality Project, "A beginner's guide to Air Quality Instant-Cast and Now-Cast" [online] https://aqicn.org/faq/2015-03-15/air-quality-nowcast-a-beginners-guide/.

Box 2
Technical note: air pollutants, their sources and effects on human and environmental health

Polluting elements	Short definition	Sources of the pollutant	Effects on human and environmental health
Nitrogen dioxide (NO_2) 	Results from the oxidation of atmospheric nitrogen (N_2, the main component of air).	• Mainly vehicle traffic, especially those with **diesel** engines. • **High-temperature industrial facilities and power plants.**	• Bronchitis and asthma. • Respiratory infections. • Reduces lung **function** and growth. • Exposure linked to **premature mortality and morbidity** from cardiovascular and respiratory diseases.
Particulate matter ($PM_{2.5}$ and PM_{10}) 	Inhalable and breathable particles composed of sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.	• Primary source: particulate matter emitted **directly** to the atmosphere, naturally or as a result of human activity, **(the burning of fossil fuels, vehicle engines, industrial processes).** • Secondary source: particulate matter produced in the atmosphere as a **result of chemical reactions from precursor gases** (of anthropogenic origin in 40%-70% of cases).	• These are the air pollutants most hazardous to human health when they enter the respiratory system ($PM_{2.5}$ → Alveoli. PM_{10} → bloodstream). • Increased mortality and morbidity from respiratory and cardiovascular causes. • Environmental effects on **plant growth, temperature** changes and alteration in **precipitation** patterns.
Sulfur dioxide (SO_2) 	Results from the burning of fossil fuels containing sulfur (oil, solid fuels).	• Burning of **fossil fuels** (coal and oil) and the smelting of mineral ores containing **sulfur.** • Main emitter →Industrial sector.	• Irritation and inflammation of the respiratory system, lung conditions and insufficiencies, asthma and chronic bronchitis, alteration of protein metabolism, headache or anxiety). • Eye irritation. • Its oxidation forms sulfuric acid (acid rain).

Source: World Health Organization (WHO), "Ambient air pollution: pollutants" [online] https://www.who.int/airpollution/ambient/pollutants/en/ and Ministry for Ecological Transition and Demographic Challenge of Spain, "Efectos en la salud y ecosistemas" [online] https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/calidad-del-aire/salud/.

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