The impact of the COVID-19 related lockdowns on air quality

Arina Bogomolova¹, Igor Balk², Natalia Polkovnikova² and Natalya Ivaschenko¹

¹ Lomonosov Moscow State University, GSP- 1, Leninskie Gory, Moscow, 119991, Russia
² Global innovation Labs LLC, 258 Harvard Str #352 Brookline MA 02446 USA

E-mail: info@innovationlabs.net

Abstract. Lockdowns imposed on population around the world due to COVID-19 provided unique opportunity to study impact of humankind of the environment. In this paper we discuss the magnitude of the anthropogenic impact on climate change, and in particular on-air pollution, since these two phenomena are interconnected. We used daily data on air pollution in several large cities, where serious restrictive measures were introduced in the context of a pandemic for a large number of citizens. The study period includes several months of 2020, including the moment of quarantine introduction, as well as the same period of 2019. Thus, we will check whether the impact of human activities on climate change is significant.

1. Introduction

The United Nations called climate change one of the defining problems of our time [1]. There are many organizations all over the world, both local and international, that study this problem and develop strategies to reduce the danger of global warming, ice melting and sea level rise. United Nations Environment and World Meteorological Organization (WMO) regularly hold global events for politicians and the public to inform them about the environmental situation in the world. Thus, this topic is actively cultivated not only in social sphere, but also influence on policy-making and economic decisions (for example Clean Air Act in US).

Climate change is most often considered in the context of anthropogenic impact on the environment. Scientists have identified a long-term relationship between human demography and production and climate change throughout the history [2]. Promoting economic prosperity while environmental conservation makes the topic of sustainable development more relevant with the lapse of time.

There are a number of articles where the authors analyze and predict the level of pollutants emitted by human activities. Carbon dioxide (CO2), nitrogen dioxide (NO2), ozone (O3) and fine particulate matter (PM2.5) are often used in studies as a reason for the transition to energy-efficient production, electric vehicles and a ban on emissions of harmful substances into the atmosphere. The main variables in forecasting models of pollutants level are traffic and meteorological variables [3, 4]. However, most models are based on assumptions, since there was no possibility to conduct an experiment.

Currently in the context of the Covid-19 pandemic and the subsequent lockdown of many cities we can observe a natural experiment on human impact on the environment. Being in quarantine, people do not use vehicles, do not fly on airplanes, and do not work in industries (except for the life support organizations). European Space Agency published a series of satellite imagery that show a significant reduction in nitrogen dioxide emissions during lockdown [5]. There are also studies that shows the reduction of pollutants during the lockdown period in India [6], Kazakhstan [7], China [8], Brazil [9].
It worth to mention, there are several unobvious insights. For example, in China [8], where cities were completely paralyzed, the reduction in pollution was not as significant as authors expected. They attributed this to adverse weather conditions. And in other regions [7, 9] ozone (O3) level increased during the lockdown period. Corinne Le Quéré and et. also found a decrease of CO2 emissions by 17% during lockdown related to 2019 [10]. But the authors also notice that decrease in global CO2 emissions is the same as seasonal amplitude. Moreover, the results obtained by the authors are a model assessment based on a combination of various indicators of human activity, grouped into sectors: power, industry, surface transport, public buildings and commerce, residential and aviation. The International Energy Agency expects decrease in CO2 emissions by 8% [11].

In this research we verify the magnitude of the human activity impact on climate change, and in particular on air pollution, since these two phenomena are interconnected [12]. We used daily data on air pollution in several large cities, where serious restrictive measures were introduced in the context of a pandemic for a large number of citizens. The study period includes several months of 2020, including the moment of quarantine introduction, as well as the same period of 2019. Thus, we will check whether the impact of human activities on climate change is significant.

2. Methodology and data
The main data source for the study is the World Air Quality Historical Database [13]. There are data on ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2) and particulate matter (PM2.5, PM10) which usually are the main indicators of air pollution. However, the database has some missing values. Separate days were modeled by average between the previous and subsequent meanings. In some cases, measurements were not available for a longer period that we didn’t model. For the purpose of this research we chose PM2.5 and O3. In the cities, we searched for research stations closest to the city center with the most exhaustive data.

The dispersion of air quality indicators is large, so it is difficult to see any patterns other than seasonal. We smoothed out the volatility by applying the moving average method [14], when the adjusted value is calculated as the average between the value in a given period (t), two previous (t-1, t-2) and two following (t+1, t+2) measurements. Thus, we maintained the dynamics, but smoothed out extreme points.

We also built trends using linear regression as maximum smoothing of daily fluctuations. Conclusions can be also drawn based on how trends are located relative to each other. For example, if the trends coincide, we can say that the new conditions did not affect the level of emissions. If one of the trends has a smaller angle of inclination, this indicates a gradual decrease in the level of pollution. The distance between the trends indicates the magnitude of the changes.

The first city in our study is Wuhan. This is one of the first places where restrictions were introduced, and more than 11 million people live in the city. The city was closed on January 23, so we chose 2 similar periods in 2018/2019 and 2019/2020 from December 1 to May 19 (Fig. 1).

It should be noted that the level of pollution in the city is quite high and is considered unhealthy, especially for sensitive groups of the population. The standard deviation of the data for the last 2 years is 35,17 and it doesn’t change much in 2020 compared to 2019 (32,37 and 33,03). Nevertheless, a pause in human activity was reflected on average PM concentration in the air (Tab. 1).

| PM2.5 Averages | Before lockdown (1 Dec – 22 Jan) | After lockdown (23 Jan – 19 May) |
|----------------|---------------------------------|----------------------------------|
| 2019           | $T_{00}$                        | 164,4                            | $T_{01}$                        | 142,3                           |
| 2020           | $T_{10}$                        | 154,5                            | $T_{11}$                        | 119,9                           |
Figure 1. PM2.5 emissions in Wuhan in 2019–2020 smoothed using the moving average.

Referring to Table 1 we can calculate the net effect \( (T_{11} - T_{10}) - (T_{01} - T_{00}) \) of the lockdown. We get a decrease in concentration of PM2.5 by 12.5 mg/m³ which is almost 8% of the average for the 2019 study period. This is a rather small decrease, especially against the background of the standard deviation.

Now let's look at ozone (O3) in Fig. 2. The concentration of O3 in 2020 is higher than in 2019. So this phenomenon is not only found in Kazakhstan [7] and Brazil [9].

Figure 2. O3 emissions in Wuhan in 2019–2020 smoothed using the moving average.

Let's calculate the net effect, using Table 2. In absolute terms, the ozone concentration changed by 4.9 points, which is approximately 14% of the average for 2019.

Table 2. Average O3 concentrations in air in Wuhan.

| O3 Averages | Before lockdown (1 Dec – 22 Jan) | After lockdown (23 Jan – 19 May) |
|-------------|----------------------------------|----------------------------------|
| 2019        | 19.2                             | 40.9                             |
| 2020        | 18.2                             | 44.8                             |
The next city we consider is London with almost 9 million inhabitants was quarantined on March 23, 2020. Let's look at the same time period and the same indicators PM2.5 and ozone (O3) on the chart (Fig. 3).

Figure 3. PM2.5 emissions in London in 2019-2020 smoothed using the moving average.

The average concentration of particulate matter (PM2.5) in the air does not exceed dangerous breakpoint, so it is not harmful for health. In London, there were significant changes in the concentration of PM2.5 before the quarantine. At the end of February 2019, there was a peak in PM2.5 concentration, which reached 127 ug/m3. That is already considered as dangerous for sensitive populations. At the same time, in 2020 there was a decline in concentration to no risk breakpoint (21 ug/m3). Therefore, we studied the longer period before quarantine in order to see the dynamics, leveling the influence of this Februarys’ periods. Let's look at the averages in Table 3.

Table 3. Average PM2.5 concentrations in air in London.

| PM2.5 Averages | Before lockdown (1 Dec – 22 Mar) | After lockdown (23 Mar – 19 May) |
|----------------|---------------------------------|---------------------------------|
| 2019           | 45,7                            | 59,8                            |
| 2020           | 41,7                            | 50,7                            |

The net effect on PM concentration in London is a decrease of 5 ug/m3 that is also about 10% relative to the average for the period of 2019. Now let's move on to ozone study (Fig. 4 and Tab. 4).

Figure 4. O3 emissions in London in 2019-2020 smoothed using the moving average.
Table 4. Average O3 concentrations in air in London.

| O3 Averages | Before lockdown (1 Dec – 22 Mar) | After lockdown (23 Mar – 19 May) |
|-------------|----------------------------------|----------------------------------|
| 2019        | 16,9                             | 27,0                             |
| 2020        | 19,4                             | 31,4                             |

As we can see on the graph (Fig.4), there is also an increase in the concentration of ozone (O3) in London in 2020. But the net effect is only 2 points (which is still 9% of the average for the 2019 period).

Let’s take another city from the other side of the Earth. About 20 million people live in New Delhi (India) and it is considered as one of the most polluted cities in the world. The concentration of particulate matter (PM2.5) in the air sometimes crosses the dangerous breakpoint of 300 ug/m3 which is considered as “Hazardous” and everybody is recommended to wear respiratory protection (Fig.5). Quarantine introduced on March 25 in India.

Figure 5. PM2.5 emissions in New Delhi in 2019-2020 smoothed using the moving average.

Table 5. Average PM2.5 concentrations in air in New Delhi.

| PM2.5 Averages | Before lockdown (1 Dec – 24 Mar) | After lockdown (25 Mar – 19 May) |
|----------------|----------------------------------|----------------------------------|
| 2019           | 201,8                            | 151,0                            |
| 2020           | 194,2                            | 106,1                            |

Based on the graph, we are able to conclude that after the implementation of restrictions, air pollution actually decreased. The net effect is 37,3 ug/m3 and air quality is close to normal (Tab.5).

The next phase of the study is calculation of air pollution by ozone (O3), but an atypical situation arose here (Fig. 6). There is a huge decrease in ozone levels, which began long before any restrictions. Therefore, most likely this is not associated with the lockdown. Another reason for such result is poor data. In any case, we will not be able to calculate the effect of lockdown on ozone level in this city.
The last city we will explore is on another continent – New York. This city is also populous, more than 8 million people live in there and they also stayed at home due to severe restrictions since March 23. There is also a decrease in air pollution by PM2.5 (Fig. 7) and the net effect is -4 ug/m3 (12% of the average for the 2019 period).

### 3. Conclusions and future research

We examined several large cities located in different parts of the world and investigated how the introduction of restrictive measures on human activity affected the climate change and air quality. In every city we studied there are millions of people, whose life paused due to a global pandemic. Based on the data obtained, we can say that the concentration of particulate matter (PM2.5) in the air decreased by about 10% in large cities all over the world. But the ozone concentration in many cases increased. This happens when the city’s population is obliged to stay at home, most of the human activity is stopped, except for the most necessary services. Global Energy Review 2020 display a 25% decline in energy demand in countries that have imposed full lockdown measures [15]. At the same time, the economy is in great shock, and the state is forced to support business and citizens. We chose large cities for research, since the introduction of quarantine measures substantially affected lives of millions of...
people and many industries, which in turn should give the maximum effect on the environment and climate in comparison with smaller cities.

The next logical step for the current research would be adding meteorological variables to the study, such as precipitation, wind and atmospheric pressure, to better calculate net anthropogenic effect while exploring more cities and pollutants. It will be especially interesting to study CO2 under the condition that reliable data is available, since there are already insights that dynamics of carbon dioxide has only predictable seasonal fluctuations [16]. Carbon dioxide is also considered as one of the causes of global warming [17].

The impact of human activities on the environment is undeniable. However, it is possible that we overestimate it. Even if people can reduce anthropogenic pollution to the level of the last few months without harming the economy (for example, everyone will switch to energy efficiency, electric transport, etc.), we may see insufficient global changes. Moreover, new challenges may arise, such as increasing ozone level in our study. The current conditions have made it possible to study many ecological phenomena.

References
[1] The United Nations 2019 Climate Change
[2] Bevana A, Colledgea S et al C 2017 Holocene fluctuations in human population demonstrate repeated links to food production and climate Proceedings of the National Academy of Sciences 114 (49)
[3] Agirre-Basurkoa E, Ibarra-Berastegib G and Madariagac I 2006 Regression and multilayer perceptron-based models to forecast hourly O3 and NO2 levels in the Bilbao area Environmental Modelling & Software 21 (4) pp 430–446
[4] Venkanna R, Nikhil G N et al 2015 Environmental monitoring of surface ozone and other trace gases over different time scales: chemistry, transport and modeling International Journal of Environmental Science and Technology 12 pp 1749–1758
[5] European Space Agency 2020 Air pollution remains low as Europeans stay at home
[6] Mahato S, Pal S and Ghosh K G 2020 Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India The Science of the total environment 730 139086
[7] Kerimray A, Baimatova N et al 2020 Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan The Science of the total environment 730 139179
[8] Wang P, Chen K, Zhu S, Wang P and Zhang H 2020 Severe air pollution events not avoided by reduced anthropogenic activities during COVID-19 outbreak Resources, conservation, and recycling 158 104814
[9] Nakada L Y K and Urban R C 2020 COVID-19 pandemic: Impacts on the air quality during the partial lockdown in Sao Paulo state, Brazil The Science of the total environment 730 139087
[10] Le Quéré C, Jackson R B, Jones M W et al 2020 Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement Nature Climate Change
[11] Can we see a change in the CO2 record because of COVID-19? 2020 (Earth System Research Laboratories, Global Monitoring Laboratory)
[12] Tai A P K, Mickley L J and Jacob D J 2012 Impact of 2000–2050 climate change on fine particulate matter (PM2.5) air quality inferred from a multi-model analysis of meteorological modes Atmospheric chemistry and physics 12 (23) pp 11329–11337
[13] Air Quality Historical Database
[14] Steve A 2013 Technical Analysis from A to Z (McGraw-Hill Education; 2 edition)
[15] Global Energy Review 2020 (International Energy Agency)
[16] Trends in Atmospheric Carbon Dioxide 2020 (Global Monitoring Laboratory)
[17] Cook J 2010 The significance of the CO2 lag Skeptical Science

Published under licence in Journal IOP Conference Series Earth and Environmental Science