SHORT-LIVED CLIMATE POLLUTANTS SPECIAL EDITION RESEARCH DIGEST

Covid-19 and Air Pollution

The SAP and the Secretariat have prepared this special edition of the SLCP research digest for the purpose of informing the Climate and Clean Air Coalition partnership of the latest and on-going research and potential links between covid-19 and air pollution and SLCPs. The SAP has not evaluated the content of the publications.

All SLCP research digests are available on the CCAC website (http://ccacoalition.org/en/research-digest)

The Scientific Advisory Panel

of the

Table of Contents

CHANGES IN EMISSIONS DUE TO COVID-19 RESPONSE

COVID-19 as a factor influencing air pollution?

Journal pre-proof

At the end of 2019, the first cases of pneumonia associated with coronavirus (COVID-19) were reported in Wuhan, China (Huang et al., 2020). Thereafter, the number of infected people increased rapidly and, a month later, the outbreak turned into a national crisis, with infected individuals diagnosed all over the country (CDC, 2020; Chan et al., 2020; World Health Organization, 2020a; 2020b). Chinese authorities shut down transportation and travel in and out of Wuhan. They also curtailed and reduced local business travel, closed down schools, colleges and universities in order to reduce the spread of the disease and established numerous quarantines (Wilder-Smith and Freedman, 2020). The maps in Fig. 1 show the nitrogen dioxide (NO_2) concentrations, resulting primarily from the burning of fossil fuels (He et al., 2020a,b), prior to and following the quarantine, with a massive reduction observed in concentrations after the corona virus outbreak (NASA, 2020). The data were collected by the Tropospheric Monitoring Instruments (TROPOMI) on-board ESA's Sentinel-5 satellite. A related sensor, the Ozone Monitoring Instrument (OMI) on-board NASA's Aura satellite, recorded similar atmospheric changes. NO_2 is a common tracer of air pollution/industrial activity, associated with morbidity and mortality (He et al., 2020a,b). NASA scientists have commented that the reduction in NO_2 pollution was first apparent near Wuhan, but spread across the rest of the country, and eventually worldwide (NASA, 2020). In Central China, NO_2 emissions were reduced by as much as 30% (NASA, 2020). CO_2 emissions, another common tracer of air pollution (Hanaoka and Masui, 2019), decreased by 25% in China and by 6% worldwide (CarbonBrief, 2020). Air pollution is responsible for many deaths and increased incidences of respiratory disease (Brauer, 2010). According to the World Health Organization, 4.6 million individuals die annually from diseases and illnesses directly related to poor air quality (Cohen et al., 2017). Poor air quality is responsible for more deaths each year than motor vehicle accidents (European Environment Agency, 2005). The impact of air pollution is a global problem and includes developed countries, such as the European nations where 193,000 people died in 2012 from airborne particulate matter (Ortiz et al., 2017). Air pollution associated deaths include but are not limited to aggravated asthma, bronchitis, emphysema, lung and heart diseases, and respiratory allergies (Brauer, 2010). China, where the COVID-19 epidemic started, is also a country severely affected by air pollution (He et al., 2020a,b).

Air pollution in China was responsible for 4000 preventable deaths each day i.e. 1.6 million fatalities in 2016 (Rohde and Muller, 2015; Wang et al., 2012). Several models predict mortality due to air pollution (Hoek et al., 2013), with an increase of all-cause mortality ranging from 0.13% per 10µg/m3 of NO_2 per day (He et al., 2020a,b) to 2% per 10µg/m3 of NO_2 on a 5 day period (Chiusolo et al., 2011), or a global hazard ratio of 1.052 (95 confidence intervals 1.045 to 1.059) per increase of 8.1 ppb in NO_2 (Crouse et al., 2015). In a hypothetical scenario in which the impact of air pollution on mortality was underestimated using the aforementioned models, and in which we considered a time period of two months with a decrease in NO_2 air pollution in China, macabre predictions could postulate a 6% reduction in mortality due to air pollution (i.e. around 100 000 life's saved, just in China). Similar calculations could be applied to other countries. At the time of writing this, there are 3,158 reported deaths from COVID-19 in China and 4,607 worldwide. Considering the huge decrease in air pollution following the quarantine (China's CO_2 emissions decreased by a quarter), the COVID-19 pandemic might paradoxically have decreased the total number of deaths during this period, by drastically decreasing the number of fatalities due to air pollution. Moreover, in addition to the reduced number of deaths due to air pollution, the reduction in air pollution itself could also have positive benefits in reducing preventable non communicable diseases (Chen and Bloom, 2019; Neira et al., 2018).

Frédéric Dutheil, Julien S.Baker, Valentin Navel. "COVID-19 as a factor influencing air pollution?" Environmental Pollution 263(Part A) (August 2020). https://www.sciencedirect.com/science/article/pii/S0269749120316468?via%3Dihub

COVID-19, City Lockdown, and Air Pollution Evidence from China

The rapid spread of COVID-19 is a global public health challenge. To prevent the escalation of its transmission, China locked down one-third of its cities and strictly restricted human mobility and economic activities. Using timely and comprehensive air quality data in China, we show that these counter-COVID-19 measures led to remarkable improvement in air quality. Within weeks, the Air Quality Index and PM2.5 concentrations were brought down by 25%. The effects are larger in colder, richer, and more industrialized cities. We estimate that such improvement would avert 24,000 to 36,000 premature deaths from air pollution on a monthly basis.

He, Guojun, Yuhang Pan, and Takanao Tanaka. "COVID-19, City Lockdown, and Air Pollution: Evidence from China." medRxiv (2020).

Good in The Worst: Covid-19 Restrictions and Ease in Global Air Pollution

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), known to cause 2019-coronavirus disease (COVID-19) pandemic is a zoonotic coronavirus and crosses species to infect human populations, where an efficient transmission of virus occurs human-to-human. Nationwide lockdown is being adopted to stop public transport, keep people at their homes and out of their work, and maintain social distancing. In turn, large geographic areas in the world (including China, Italy, Spain, and USA) has been almost halted. This temporary halt is significantly slashing down the air pollution (air pollutants and warming gases) in most cities across the world. This paper: (i) introduces both COVID-19 and air pollution; (ii) overviews the relation of air pollution with respiratory/lung diseases; (iii) compiles and highlights major data appeared in media and journals reporting lowering of air pollution in major cities those have been highly impacted by the COVID-19; and also (iv) lists the way forward in the present context. Because COVID-19 is an ongoing pandemic and currently far from over, strong conclusions could not be drawn with very limited data at present. The temporary slashed down global air pollution as a result of COVID-19 restrictions are expected to stimulate the researchers, policy makers and governments for the judicious use of resources; thereby minimise the global emissions, and maintain their economies once the pandemic eases. On the other, lifting of the nationwide lockdown and eventual normalisation of the temporarily halted sectors may also reverse the currently COVID-19 pandemic-led significantly slashed down global air pollution that could make the future respiratory health crisis grimmer.

Anjum, N.A. Good in The Worst: COVID-19 Restrictions and Ease in Global Air Pollution. Preprints 2020, 2020040069 (doi: 10.20944/preprints202004.0069.v1). https://www.preprints.org/manuscript/202004.0069/v1

Severe air pollution events not avoided by reduced anthropogenic activities during Covid-19 outbreak

Due to the pandemic of coronavirus disease 2019 in China, almost all avoidable activities in China are prohibited since Wuhan announced lockdown on January 23, 2020. With reduced activities, severe air pollution events still occurred in the North China Plain, causing discussions regarding why severe air pollution was not avoided. The Community Multi-scale Air Quality model was applied during January 01 to February 12, 2020 to study PM2.5 changes under emission reduction scenarios. The estimated emission reduction case (Case 3) better reproduced PM2.5. Compared with the case without emission change (Case 1), Case 3 predicted that PM2.5 concentrations decreased by up to 20% with absolute decreases of 5.35, 6.37, 9.23, 10.25, 10.30, 12.14, 12.75, 14.41, 18.00 and 30.79 μg/m3 in Guangzhou, Shanghai, Beijing,

Shijiazhuang, Tianjin, Jinan, Taiyuan, Xi'an, Zhengzhou, Wuhan, respectively. In high-pollution days with PM2.5 greater than 75 μg/m3, the reductions of PM2.5 in Case 3 were 7.78, 9.51, 11.38, 13.42, 13.64, 14.15, 14.42, 16.95 and 22.08 μg/m3 in Shanghai, Jinan, Shijiazhuang, Beijing, Taiyuan, Xi'an, Tianjin, Zhengzhou and Wuhan, respectively. The reductions in emissions of PM2.5 precursors were ~2 times of that in concentrations, indicating that meteorology was unfavorable during simulation episode. A further analysis shows that benefits of emission reductions were overwhelmed by adverse meteorology and severe air pollution events were not avoided. This study highlights that large emissions reduction in transportation and slight reduction in industrial would not help avoid severe air pollution in China, especially when meteorology is unfavorable. More efforts should be made to completely avoid severe air pollution.

Wang, Pengfei, et al. "Severe air pollution events not avoided by reduced anthropogenic activities during COVID-19 outbreak." Resources, Conservation and Recycling 158 (2020): 104814.

The Effects of Outdoor Air Pollution Concentrations and Lockdowns on Covid-19 Infections in Wuhan and Other Provincial Capitals in China

Background: Covid-19 was first reported in Wuhan, China in Dec 2019. Since then, it has been transmitted rapidly in China and the rest of the world. While Covid-19 transmission rate has been declining in China, it is increasing exponentially in Europe and America. Although there are numerous studies examining Covid-19 infection, including an archived paper looking into the meteorological effect, the role of outdoor air pollution has yet to be explored rigorously. It has been shown that air pollution will weaken the immune system, and increase the rate of respiratory virus infection. We postulate that outdoor air pollution concentrations will have a negative effect on Covid-19 infections in China, whilst lockdowns, characterized by strong social distancing and home isolation measures, will help to moderate such negative effect.

Methods: We will collect the number of daily confirmed Covid-19 cases in 31 provincial capital cities in China during the period of 1 Dec 2019 to 20 Mar 2020 (from a popular Chinese online platform which aggregates all cases reported by the Chinese national/provincial health authorities). We will also collect daily air pollution and meteorology data at the city-level (from the Chinese National Environmental Monitoring Center and the US National Climatic Data Center), daily inter-city migration flows and intra-city movements (from Baidu). City-level demographics including age distribution and gender, education, and median household income can be obtained from the statistical yearbooks. City-level co-morbidity indicators including rates of chronic disease and co-infection can be obtained from related research articles. A regression model is developed to model the relationship between the infection rate of Covid-19 (number of confirmed cases/population at the city level) and outdoor air pollution at the city level, after taking into account confounding factors such as meteorology, inter- and intra-city movements, demographics, and co-morbidity and co-infection rates. In particular, we shall study how air pollution affects infection rates across different cities, including Wuhan. Our model will also study air pollution would affect infection rates in Wuhan before and after the lockdown. Expected findings: We expect there be a correlation between Covid-19 infection rate and outdoor air pollution. We also expect that reduced intra-city movement after the lockdowns in Wuhan and the rest of China will play an important role in reducing the infection rate. Interpretation: Infection rate is growing exponentially in major cities worldwide. We expect Covid-19 infection rate is related to the air pollution concentration, and is strongly dependent on inter- and intra-city movements. To reduce the infection rate, the international community may deploy effective air pollution reduction plans and social distancing policies.

Han, Yang, et al. "The Effects of Outdoor Air Pollution Concentrations and Lockdowns on Covid-19 Infections in Wuhan and Other Provincial Capitals in China." (2020).

Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic

Lockdown measures came into force in Spain from March 14th, two weeks after the start of the SARS-CoV-2 epidemic, to reduce the epidemic curve. Our study aims to describe changes in air pollution levels during the lockdown measures in the city of Barcelona (NE Spain), by studying the time evolution of atmospheric pollutants recorded at the urban background and traffic air quality monitoring stations. After two weeks of lockdown, urban air pollution markedly decreased but with substantial differences among pollutants. The most significant reduction was estimated for BC and NO2 (-45 to -51%), pollutants mainly related to traffic emissions. A lower reduction was observed for PM10 (-28 to -31.0%). By contrast, O3 levels increased (+33 to +57% of the 8 h daily maxima), probably due to lower titration of O3 by NO and the decrease of NOx in a VOC-limited environment. Relevant differences in the meteorology of these two periods were also evidenced. The low reduction for PM10 is probably related to a significant regional contribution and the prevailing secondary origin of fine aerosols, but an in-depth evaluation has to be carried out to interpret this lower decrease. There is no defined trend for the low SO2 levels, probably due to the preferential reduction in emissions from the least polluting ships. A reduction of most pollutants to minimal concentrations are expected for the forthcoming weeks because of the more restrictive actions implemented for a total lockdown, which entered into force on March 30th. There are still open questions on why PM10 levels were much less reduced than BC and NO2 and on what is the proportion of the abatement of pollution directly related to the lockdown, without meteorological interferences.

Tobías, Aurelio, et al. "Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic." Science of The Total Environment (2020): 138540.

Abrupt declines in tropospheric nitrogen dioxide over China after the outbreak of COVID-19

China's policy interventions to reduce the spread of the coronavirus disease 2019 have environmental and economic impacts. Tropospheric nitrogen dioxide indicates economic activities, as nitrogen dioxide is primarily emitted from fossil fuel consumption. Satellite measurements show a 48% drop in tropospheric nitrogen dioxide vertical column densities from the 20 days averaged before the 2020 Lunar New Year to the 20 days averaged after. This is 20% larger than that from recent years. We relate to this reduction to two of the government's actions: the announcement of the first report in each province and the date of a province's lockdown. Both actions are associated with nearly the same magnitude of reductions. Our analysis offers insights into the unintended environmental and economic consequences through reduced economic activities.

Liu, Fei, et al. "Abrupt declines in tropospheric nitrogen dioxide over China after the outbreak." arXiv.2004.06542.

Biomass use and COVID-19: A novel concern

Evidence supports the link between air pollution and COVID-19 and thus it is likely that exposure to biomass smoke is associated with COVID-19. The poor, including refugees and migrant workers staying in fragile conditions, are most vulnerable. An outbreak of COVID-19 in a place where the concept of physical distancing is next to impossible could easily overwhelm the public health system. It is thus essential to understand the consequences of being exposed to smoke in relation to COVID-19 infection.

Thakur, Megha, et al. "Biomass use and COVID-19: A novel concern." Environmental Research (2020): 109586.

A preliminary assessment of the impact of COVID-19 on environment – A case study of China

The coronavirus disease (COVID-19) is seriously threatening world public health security. Currently, >200 countries and regions have been affected by the epidemic, with the number of infections and deaths still

increasing. As an extreme event, the outbreak of COVID-19 has greatly damaged the global economic growth and caused a certain impact on the environment. This paper takes China as a case study, comprehensively evaluating the dynamic impact of COVID-19 on the environment. The analysis results indicate that the outbreak of COVID-19 improves China's air quality in the short term and significantly contributes to global carbon emission reduction. However, in the long run, there is no evidence that this improvement will continue. When China completely lifts the lockdown and resumes large-scale industrial production, its energy use and greenhouse gas (GHG) emissions are likely to exceed the level before the event. Moreover, COVID-19 significantly reduces the concentration of nitrogen dioxide (NO2) in the atmosphere. The decline initially occurred near Wuhan and eventually spread to the whole country. The above phenomenon shows that the decreasing economic activities and traffic restrictions directly lead to the changes of China's energy consumption and further prevent the environment from pollution. The results in this study support the fact that strict quarantine measures can not only protect the public from COVID-19, but also exert a positive impact on the environment. These findings can provide a reference for other countries to assess the influence of COVID-19 on the environment.

Wang, Qiang, and Min Su. "A preliminary assessment of the impact of COVID-19 on environment–A case study of China." Science of The Total Environment (2020): 138915.

Does lockdown reduce air pollution? Evidence from 44 cities in northern China

Responding to the ongoing novel coronavirus (agent of COVID-19) outbreak, China implemented “the largest quarantine in human history” in an attempt to prevent the spread of the virus on 23 January 2020. Human mobility and relevant production and consumption activities have since decreased significantly. As a likely side effect of this decrease, many regions have recorded significant reductions in air pollution. We employed daily air pollution data and Intracity Migration Index (IMI) data form Baidu between 1 January and 21 March 2020 for 44 cities in northern China to examine whether, how, and to what extent travel restrictions affected air quality. On the basis of this quantitative analysis, we reached the following conclusions: (1) The reduction of air pollution was strongly associated with travel restrictions during this pandemic—on average, the air quality index (AQI) decreased by 7.80%, and five air pollutants (i.e., SO2, PM2.5, PM10, NO2, and CO) decreased by 6.76%, 5.93%, 13.66%, 24.67%, and 4.58%, respectively. (2) Mechanism analysis illustrated that the lockdowns of 44 cities reduced human movements by 69.85%, and a reduction in the AQI, PM2.5, and CO was partially mediated by human mobility, and SO2, PM10, and NO2 were completely mediated. (3) Our findings highlight the importance of understanding the role of green production and consumption.

Rui, Bao and Achen Zhang. “Does lockdown reduce air pollution? Evidence from 44 cities in northern China.” Science of The Total Environment (2020): 139052

Exploring Dependence of COVID-19 on Environmental Factors and Spread Prediction in India

The pandemic of “Corona Virus Disease 2019” or COVID-19 has taken the world by storm. Majority of nations of the world have been challenged by the novel coronavirus, which is supposedly of zoonotic origin and is known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The present work attempts to evaluate the spread of COVID-19 in India. The methodology of assessment uses SEIR (Susceptible-Exposed-Infectious-Removed) model to establish the impact of socio-behavioural aspect, especially social distancing, affecting the numbers of COVID-19 cases per day. The lockdown initiated by Government of India (GoI) scenario is weighed against a scenario with a possible initiation of community spread due to crowded gatherings in India. The resultant changes, as against the lockdown scenario, has been reported in terms of the increase in the number of cases and stretch of the timeline to mitigate the COVID-19 spread. Impact of environmental factors like temperature and relative humidity have also been analyzed using statistical methods, including Response Surface Methodology (RSM) and Correlation. It has been found that the spread of cases is dependent on environmental conditions, i.e. temperature

and relative humidity. This study is expected to help the policymakers and stakeholders to device an improved action plan to alleviate the COVID-19 spread, especially in India.

Bherwani, H., et al. "Exploring Dependence of COVID-19 on Environmental Factors and Spread Prediction in India." (2020).

Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan

Number of cities worlwide experienced air quality improvements during COVID-19 lockdowns; however, such changes may have been different in places with major contributions from nontraffic related sources. In Almaty, a city-scale quarantine came into force on March 19, 2020, which was a week after the first COVID-19 case was registered in Kazakhstan. This study aims to analyze the effect of the lockdown from March 19 to April 14, 2020 (27 days), on the concentrations of air pollutants in Almaty. Daily concentrations of PM2.5, NO2, SO2, CO, O3, and BTEX were compared between the periods before and during the lockdown. During the lockdown, the PM2.5 concentration was reduced by 21% with spatial variations of 6–34% compared to the average on the same days in 2018 – 2019, and still, it exceeded WHO daily limit values for 18 days. There were also substantial reductions in CO and NO2 concentrations by 49% and 35%, respectively, but an increase in O3 levels by 15% compared to the prior 17 days before the lockdown. The concentrations of benzene and toluene were 2–3 times higher than those during in the same seasons of 2015–2019. The temporal reductions may not be directly attributed to the lockdown due to favorable meteorological variations during the period, but the spatial effects of the quarantine on the pollution levels are evidenced. The results demonstrate the impact of traffic on the complex nature of air pollution in Almaty, which is substantially contributed by various nontraffic related sources, mainly coal-fired combined heat and power plants and household heating systems, as well as possible small irregular sources such as garbage burning and bathhouses.

Kerimray, Aiymgul, et al. "Assessing air quality changes in large cities during COVID-19 lockdowns: The impacts of traffic-free urban conditions in Almaty, Kazakhstan." Science of The Total Environment (2020): 139179.

Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India

Amid the COVID-19 pandemic, a nationwide lockdown is imposed in India initially for three weeks from 24th March to 14th April 2020 and extended up to 3rd May 2020. Due to the forced restrictions, pollution level in cities across the country drastically slowed down just within few days which magnetize discussions regarding lockdown to be the effectual alternative measures to be implemented for controlling air pollution. The present article eventually worked on this direction to look upon the air quality scenario amidst the lockdown period scientifically with special reference to the megacity Delhi. With the aid of air quality data of seven pollutant parameters (PM10, PM2.5, SO2, NO2, CO, O3 and NH3) for 34 monitoring stations spread over the megacity we have employed National Air Quality Index (NAQI) to show the spatial pattern of air quality in pre and during-lockdown phases. The results demonstrated that during lockdown air quality is significantly improved. Among the selected pollutants, concentrations of PM10 and PM2.5 have witnessed maximum reduction (>50%) in compare to the pre-lockdown phase. In compare to the last year (i.e. 2019) during the said time period the reduction of PM10 and PM2.5 is as high as about 60% and 39% respectively. Among other pollutants, NO2 (- 52.68%) and CO (-30.3%) level have also reduced during-lockdown phase. About 40% to 50% improvement in air quality is identified just after four days of commencing lockdown. About 54%, 49%, 43%, 37% and 31% reduction in NAQI have been observed in Central, Eastern, Southern, Western and Northern parts of the megacity. Overall, the study is thought to be a useful supplement to the regulatory bodies since it showed the pollution source control can attenuate the air quality. Temporary such source control in a suitable time interval may heal the environment.

Mahato, Susanta, Swades Pal, and Krishna Gopal Ghosh. "Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India." Science of the Total Environment (2020): 139086.

Air quality changes during the COVID-19 lockdown over the Yangtze River Delta Region: An insight into the impact of human activity pattern changes on air pollution variation

The outbreak of COVID-19 has spreaded rapidly across the world. To control the rapid dispersion of the virus, China has imposed national lockdown policies to practise social distancing. This has led to reduced human activities and hence primary air pollutant emissions, which caused improvement of air quality as a side-product. To investigate the air quality changes during the COVID-19 lockdown over the YRD Region, we apply the WRF-CAMx modelling system together with monitoring data to investigate the impact of human activity pattern changes on air quality. Results show that human activities were lowered significantly during the period: industrial operations, VKT, constructions in operation, etc. were significantly reduced, leading to lowered SO2, NO*x*, PM2.5 and VOCs emissions by approximately 16–26%, 29–47%, 27–46% and 37–57% during the Level I and Level II response periods respectively. These emission reduction has played a significant role in the improvement of air quality. Concentrations of PM2.5, NO2 and SO2 decreased by 31.8%, 45.1% and 20.4% during the Level I period; and 33.2%, 27.2% and 7.6% during the Level II period compared with 2019. However, ozone did not show any reduction and increased greatly. Our results also show that even during the lockdown, with primary emissions reduction of 15%–61%, the daily average PM2.5 concentrations range between 15 and 79 μg m -3, which shows that background and residual pollutions are still high. Source apportionment results indicate that the residual pollution of PM2.5 comes from industry (32.2–61.1%), mobile (3.9–8.1%), dust (2.6–7.7%), residential sources (2.1–28.5%) in YRD and 14.0–28.6% contribution from long-range transport coming from northern China. This indicates that in spite of the extreme reductions in primary emissions, it cannot fully tackle the current air pollution. Re-organisation of the energy and industrial strategy together with trans-regional joint-control for a full long-term air pollution plan need to be further taken into account.

Li, Li, et al. "Air quality changes during the COVID-19 lockdown over the Yangtze River Delta Region: An insight into the impact of human activity pattern changes on air pollution variation." Science of The Total Environment (2020): 139282.

Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic

An outbreak of respiratory illness which is proven to be infected by a 2019 novel coronavirus (2019-nCoV) officially named as Coronavirus Disease 2019 (COVID-19) was first detected in Wuhan, China and has spread rapidly in other parts of China as well as other countries around the world, including Malaysia. The first case in Malaysia was identified on 25 January 2020 and the number of cases continue to rise since March 2020. Therefore, 2020 Malaysia Movement Control Order (MCO) was implemented with the aim to isolate the source of the COVID-19 outbreak. As a result, there were fewer number of motor vehicles on the road and the operation of industries was suspended, ergo reducing emissions of hazardous air pollutants in the atmosphere. We had acquired the Air Pollutant Index (API) data from the Department of Environment Malaysia on hourly basis before and during the MCO with the aim to track the changes of fine particulate matter (PM2.5) at 68 air quality monitoring stations. It was found that the PM2.5 concentrations showed a high reduction of up to 58.4% during the MCO. Several red zone areas (>41 confirmed COVID-19 cases) had also reduced of up to 28.3% in the PM2.5 concentrations variation. The reduction did not solely depend on MCO, thus the researchers suggest a further study considering the influencing factors that need to be adhered to in the future.

Abdullah, Samsuri, et al. "Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic." Science of The Total Environment 729 (2020): 139022.

Air pollution reduction and mortality benefit during the COVID-19 outbreak in China

To control the coronavirus disease 2019 (COVID-19) outbreak, China adopted stringent traffic restrictions and self-quarantine measures, first in Wuhan and neighboring cities beginning Jan 23, 2020, and then 2 days later in all provinces in China (figure). The countrywide ban on traffic mobility greatly reduced transportation emissions, whereas emissions from residential heating and industry remained steady or slightly declined.1 In this Comment, we examine the change in air pollution and the potentially avoided cause-specific mortality during this large-scale quarantine.

Chen, Kai, et al. "Air Pollution Reduction and Mortality Benefit during the COVID-19 Outbreak in China." medRxiv (2020).

Changes in air quality related to the control of coronavirus in China: Implications for traffic and industrial emissions

Measures taken to control the disease (Covid-19) caused by the novel coronavirus dramatically reduced the number of vehicles on the road and diminished factory production. For this study, changes in the air quality index (AQI) and the concentrations of six air pollutants (PM2.5, PM10, CO, SO2, NO2, and O3) were evaluated during the Covid-19 control period in northern China. Overall, the air quality improved, most likely due to reduced emissions from the transportation and secondary industrial sectors. Specifically, the transportation sector was linked to the NO2 emission reductions, while lower emissions from secondary industries were the major cause for the reductions of PM2.5 and CO. The reduction in SO2 concentrations was only linked to the industrial sector. However, the reductions in emissions did not fully eliminate air pollution, and O3 actually increased, possibly because lower fine particle loadings led to less scavenging of HO2 and as a result greater O3 production. These results also highlight need to control emissions from the residential sector.

Wang, Yichen, et al. "Changes in air quality related to the control of coronavirus in China: Implications for traffic and industrial emissions." Science of The Total Environment (2020): 139133.

Effect of restricted emissions during COVID-19 on air quality in India

The effectiveness and cost are always top factors for policy-makers to decide control measures and most measures had no pre-test before implementation. Due to the COVID-19 pandemic, human activities are largely restricted in many regions in India since mid-March of 2020, and it is a progressing experiment to testify effectiveness of restricted emissions. In this study, concentrations of six criteria pollutants, PM10, PM2.5, CO, NO2, ozone and SO2 during March 16th to April 14th from 2017 to 2020 in 22 cities covering different regions of India were analysed. Overall, around 43, 31, 10, and 18% decreases in PM2.5, PM10, CO, and NO2 in India were observed during lockdown period compared to previous years. While, there were 17% increase in O3 and negligible changes in SO2. The air quality index (AQI) reduced by 44, 33, 29, 15 and 32% in north, south, east, central and western India, respectively. Correlation between cities especially in northern and eastern regions improved in 2020 compared to previous years, indicating more significant regional transport than previous years. The mean excessive risks of PM reduced by ~52% nationwide due to restricted activities in lockdown period. To eliminate the effects of possible favourable meteorology, the WRF-AERMOD model system was also applied in Delhi-NCR with actual meteorology during the lockdown period and an un-favourable event in early November of 2019 and results show that predicted PM2.5 could increase by only 33% in unfavourable meteorology. This study gives confidence to the regulatory bodies that even during unfavourable meteorology, a significant improvement in air quality could be expected if strict execution of air quality control plans is implemented.

Sharma, Shubham, et al. "Effect of restricted emissions during COVID-19 on air quality in India." Science of The

Total Environment 728 (2020): 138878.

Possible environmental effects on the spread of COVID-19 in China

At the end of 2019, a novel coronavirus, designated as SARS-CoV-2, emerged in Wuhan, China and was identified as the causal pathogen of COVID-19. The epidemic scale of COVID-19 has increased dramatically, with confirmed cases increasing across China and globally. Understanding the potential affecting factors involved in COVID-19 transmission will be of great significance in containing the spread of the epidemic. Environmental and meteorological factors might impact the occurrence of COVID-19, as these have been linked to various diseases, including severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), whose causative pathogens belong to the same virus family as SARS-CoV-2. We collected daily data of COVID-19 confirmed cases, air quality and meteorological variables of 33 locations in China for the outbreak period of 29 January 2020 to 15 February 2020. The association between air quality index (AQI) and confirmed cases was estimated through a Poisson regression model, and the effects of temperature and humidity on the AQI-confirmed cases association were analyzed. The results show that the effect of AQI on confirmed cases associated with an increase in each unit of AQI was statistically significant in several cities. The lag effect of AQI on the confirmed cases was statistically significant on lag day 1 (relative risk (RR) = 1.0009, 95% confidence interval (CI): 1.0004, 1.0013), day 2 (RR = 1.0007, 95% CI: 1.0003, 1.0012) and day 3 (RR = 1.0008, 95% CI: 1.0003, 1.0012). The AQI effect on the confirmed cases might be stronger in the temperature range of 10 °C ≤ T < 20 °C than in other temperature ranges, while the RR of COVID-19 transmission associated with AQI was higher in the relative humidity (RH) range of 10% ≤ RH < 20%. Results may suggest an enhanced impact of AQI on the COVID-19 spread under low RH.

Xu, Hao, et al. "Possible environmental effects on the spread of COVID-19 in China." Science of The Total Environment (2020): 139211.

COVID-19's impact on the atmospheric environment in the Southeast Asia region

Since its first appearance in Wuhan, China at the end of 2019, the new coronavirus (COVID-19) has evolved a global pandemic within three months, with more than 4.3 million confirmed cases worldwide until mid-May 2020. As many countries around the world, Malaysia and other southeast Asian (SEA) countries have also enforced lockdown at different degrees to contain the spread of the disease, which has brought some positive effects on natural environment. Therefore, evaluating the reduction in anthropogenic emissions due to COVID-19 and the related governmental measures to restrict its expansion is crucial to assess its impacts on air pollution and economic growth. In this study, we used aerosol optical depth (AOD) observations from Himawari-8 satellite, along with tropospheric NO2 column density from Aura-OMI over SEA, and ground-based pollution measurements at several stations across Malaysia, in order to quantify the changes in aerosol and air pollutants associated with the general shutdown of anthropogenic and industrial activities due to COVID-19. The lockdown has led to a notable decrease in AOD over SEA and in the pollution outflow over the oceanic regions, while a significant decrease (27% - 30%) in tropospheric NO2 was observed over areas not affected by seasonal biomass burning. Especially in Malaysia, PM10, PM2.5, NO2, SO2, and CO concentrations have been decreased by 26–31%, 23–32%, 63–64%, 9–20%, and 25–31%, respectively, in the urban areas during the lockdown phase, compared to the same periods in 2018 and 2019. Notable reductions are also seen at industrial, suburban and rural sites across the country. Quantifying the reductions in major and health harmful air pollutants is crucial for health-related research and for air-quality and climate-change studies.

Kanniah, Kasturi Devi, et al. "COVID-19's impact on the atmospheric environment in the Southeast Asia region." Science of The Total Environment (2020): 139658.

Emergence of Blue Sky Over Delhi Due to Coronavirus Disease (COVID-19) Lockdown Implications

Due to coronavirus pandemic (COVID-19) prevailing in more than 210 countries, out of them only few have promulgated lockdown and on March 24, 2020 India also implemented lockdown for 21 days to prevent the community spread of virus among people. Since then, lockdown heavily restricts travel movements of fights, rail, intercity bus services besides industrial activity halt throughout the country. The significant improvement in the air quality of Delhi region was observed due to strict implementation of lockdown. During the lockdown period, improvement in ambient air quality helped us in circumventing the coronavirus community spread. The preliminary results showing the decrease in horizontal advection of pollutants has given an opportunity to understand the background concentrations of air pollutants over Delhi. To analyse this peculiar situation, we have assessed the pollutants datasets collected by twelve different online ambient air quality monitoring stations (AQMS) of Central Pollution Control Board (CPCB), New Delhi, India and observed a colossal improvement in the ambient air quality. The analysis of data confirms the sharp decline in concentrations (nearly 200%) of PM2.5 and PM10. The concentration of nitrous oxides (NOx), recorded its maximum (342 ppb) on 12 January 2020 in CRRI–Mathura Road, Delhi with the lowest value as 24 ppb on 30 March 2020 (reduced to nearly 14 times of the peak value). In the triad of this infectious disease, the role of environment is not linked better however, the ground reality cannot be ignored due to environment around us receives, maintains, protects and transports the alethiological agents to host prevailing in polluted environment which makes our lungs more susceptible to viral attacks. Therefore, a cleaner environment would prove to be an effective measure to halt and reduce the transmission of viral infections.

Kotnala, Garima, et al. "Emergence of Blue Sky Over Delhi Due to Coronavirus Disease (COVID-19) Lockdown Implications." Aerosol Science and Engineering: 1.

COVID-19: air pollution remains low as people stay at home

Coronavirus diseases 2019 (COVID-19) is transmitted worldwide in over a very short time, as it was originated in late 2019 from Wuhan city, China. To reduce the possible effects due to COVID-19, some sort of lockdown activities have been applied in many countries. In this regard, the outcomes reported bonus benefits to the natural environment showing a significant decrease in air pollution worldwide due to COVID-19. The National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) released air pollution data for Asian and European countries to assess the significant changes in air quality. The main objective of the study is to compare the air quality data released by international agencies before and after the novel coronavirus pandemic.

Gautam, Sneha. "COVID-19: air pollution remains low as people stay at home." Air Quality, Atmosphere, & Health (2020): 1.

Amplified ozone pollution in cities during the COVID-19 lockdown

The effect of lockdown due to coronavirus disease (COVID-19) pandemic on air pollution in four Southern European cities (Nice, Rome, Valencia and Turin) and Wuhan (China) was quantified, with a focus on ozone (O3). Compared to the same period in 2017–2019, the daily O3 mean concentrations increased at urban stations by 24% in Nice, 14% in Rome, 27% in Turin, 2.4% in Valencia and 36% in Wuhan during the lockdown in 2020. This increase in O3 concentrations is mainly explained by an unprecedented reduction in NOx emissions leading to a lower O3 titration by NO. Strong reductions in NO2 mean concentrations were observed in all European cities, ~53% at urban stations, comparable to Wuhan (57%), and ~65% at traffic stations. NO declined even further, ~63% at urban stations and ~78% at traffic stations in Europe. Reductions in PM2.5 and PM10 at urban stations were overall much smaller both in magnitude and relative change in Europe (~8%) than in Wuhan (~42%). The PM reductions due to limiting transportation and fuel

combustion in institutional and commercial buildings were partly offset by increases of PM emissions from the activities at home in some of the cities. The NOx concentrations during the lockdown were on average 49% lower than those at weekends of the previous years in all cities. The lockdown effect on O3 production was ~10% higher than the weekend effect in Southern Europe and 38% higher in Wuhan, while for PM the lockdown had the same effect as weekends in Southern Europe (~6% of difference). This study highlights the challenge of reducing the formation of secondary pollutants such as O3 even with strict measures to control primary pollutant emissions. These results are relevant for designing abatement policies of urban pollution.

Sicard, Pierre, et al. "Amplified ozone pollution in cities during the COVID-19 lockdown." Science of The Total Environment (2020): 139542.

COVID-19 pandemic and environmental pollution: A blessing in disguise?

In late 2019, a novel infectious disease with human to human transmission (COVID-19) was identified in Wuhan China, which now has turned into a global pandemic. Countries all over the world have implemented some sort of lockdown to slow down its infection and mitigate it. Lockdown due to COVID-19 has drastic effects on social and economic fronts. However, this lockdown also has some positive effect on natural environment. Recent data released by NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) indicates that pollution in some of the epicenters of COVID-19 such as Wuhan, Italy, Spain and USA etc. has reduced up to 30%. This study compiled the environmental data released by NASA and ESA before and after the coronavirus pandemic and discusses its impact on environmental quality.

Muhammad, Sulaman, Xingle Long, and Muhammad Salman. "COVID-19 pandemic and environmental pollution: A blessing in disguise?." Science of The Total Environment (2020): 138820.

Impact of Covid-19 lockdown on PM10, SO2 and NO2 concentrations in Salé City (Morocco)

Covid-19 was first reported in Morocco on March 2, 2020. Since then, to prevent its propagation, the Moroccan government declared a state of health emergency. A set of rapid and strict countermeasures have taken, including locking down cities, limiting population's mobility and prohibiting almost all avoidable activities. In the present study, we attempted to evaluate the changes in levels of some air pollutants (mainly PM10, NO2 and SO2) in Salé city (North-Western Morocco) during the lockdown measures. In this context, a continuous measurement of PM10, SO2 and NO2 was carried before and during the Covid-19 lockdown period. As a consequence of the security measures and control actions undertaken, the emissions from vehicle exhaust and industrial production were significantly reduced, which contribute to the decrease in the concentrations of the studied pollutants. The obtained results showed that the difference between the concentrations recorded before and during the lockdown period were respectively 75%, 49% and 96% for PM10, SO2 and NO2. PM10 levels were much less reduced than NO2. The three-dimensional air mass backward trajectories, using the HYSPLIT model, demonstrated the benefits of PM10 local emission reductions related to the lockdown were overwhelmed by the contribution of long-range transported aerosols outside areas. In addition, noteworthy differences in the air mass back trajectories and the meteorology between these two periods were evidenced.

Otmani, Anas, et al. "Impact of Covid-19 lockdown on PM10, SO2 and NO2 concentrations in Salé City (Morocco)." Science of The Total Environment (2020): 139541.

The Response in Air Quality to the Reduction of Chinese Economic Activities during the COVID-19 Outbreak

During the COVID-19 outbreak that took place in early 2020, the economic activities in China were drastically reduced and accompanied by a strong reduction in the emission of primary air pollutants. On the basis of measurements made at the monitoring stations operated by the China National Environmental Monitoring Center, we quantify the reduction in surface PM2.5, NO2, CO and SO2 concentrations in northern China during the lockdown, which started on 23 January 2020. We find that, on the average, the levels of surface PM2.5 and NO2 have decreased by approximately 35 and 60 percent, respectively, between the period 1-22 January 2020 and the period 23 January-29 February 2020. At the same time, the mean ozone concentration has increased by a factor 1.5–2. In urban area of Wuhan, where drastic measures were adopted to limit the spread of the coronavirus, similar changes in the concentrations of PM2.5, NO2 and ozone are found.

Shi, Xiaoqin, and Guy P. Brasseur. "The Response in Air Quality to the Reduction of Chinese Economic Activities during the COVID‐19 Outbreak." Geophysical Research Letters (2020): e2020GL088070.

Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement

Government policies during the COVID-19 pandemic have drastically altered patterns of energy demand around the world. Many international borders were closed and populations were confined to their homes, which reduced transport and changed consumption patterns. Here we compile government policies and activity data to estimate the decrease in CO2 emissions during forced confinements. Daily global CO2 emissions decreased by –17% (–11 to –25% for ±1σ) by early April 2020 compared with the mean 2019 levels, just under half from changes in surface transport. At their peak, emissions in individual countries decreased by –26% on average. The impact on 2020 annual emissions depends on the duration of the confinement, with a low estimate of –4% (–2 to –7%) if prepandemic conditions return by mid-June, and a high estimate of –7% (–3 to –13%) if some restrictions remain worldwide until the end of 2020. Government actions and economic incentives postcrisis will likely influence the global CO2 emissions path for decades.

Le Quéré, Corinne, et al. "Temporary reduction in daily global CO 2 emissions during the COVID-19 forced confinement." Nature Climate Change (2020): 1-7.

Air Quality Variation in Wuhan, Daegu, and Tokyo during the Explosive Outbreak of COVID-19 and Its Health Effects

This study was designed to assess the variation of the air quality actually measured from the air pollution monitoring stations (AQMS) in three cities (Wuhan, Daegu, and Tokyo), in Asian countries experiencing the explosive outbreak of COVID-19, in a short period of time. In addition, we made a new attempt to calculate the reduced DosePM2.5 (μg) at the bronchiolar (Br.) and alveolar-interstitial (AI) regions of the 10-year-old children after the city lockdown/self-reflection of each city. A comparison of the average PM2.5 of a month before and after the lockdown (Wuhan) and self-reflection (Daegu and Tokyo) clearly shows that the PM2.5 concentration was decreased by 29.9, 20.9, and 3.6% in Wuhan, Daegu and Tokyo, respectively. Wuhan, Daegu and Tokyo also recorded 53.2, 19.0, and 10.4% falls of NO2 concentration, respectively. Wuhan, which had the largest decrease of PM2.5 concentration due to COVID-19, also marked the largest reduced DosePM2.5 10-year-old children (μg) (3660 μg at Br. and 6222 μg at AI), followed by Daegu (445 μg at Br. and 1287 μg at AI), and Tokyo (18 μg at Br. and 52 μg at AI), over two months after the city lockdown/self-reflection. Our results suggest that the city lockdown/self-reflection had the effect of lowering the concentration of PM2.5, resulting in an extension of the period it took to the acute allergic airway inflammation (AAI) for the 10-year-old children.

Ma, Chang-Jin, and Gong-Unn Kang. "Air Quality Variation in Wuhan, Daegu, and Tokyo during the Explosive Outbreak of COVID-19 and Its Health Effects." International Journal of Environmental Research and Public Health

17.11 (2020): 4119.

Significant changes in the chemical compositions and sources of PM2.5 in Wuhan since the city lockdown as COVID-19

Wuhan was the first city to adopt the lockdown measures to prevent COVID-19 spreading, which improved the air quality accordingly This study investigated the variations in chemical compositions, source contributions, and regional transport of fine particles (PM2 5) during January 23–February 22 of 2020, compared with the same period in 2019 The average mass concentration of PM2 5 decreased from 72 9 μ g m-3 (2019) to 45 9 μg m-3 (2020), by 27 0 μg m-3 It was predominantly contributed by the emission reduction (92 0%), retrieved from a random forest tree approach The main chemical species of PM2 5 all decreased with the reductions ranging from 0 85 μg m-3 (chloride) to 9 86 μg m-3 (nitrate) ($p < 0$ 01) Positive matrix factorization model indicated that the mass contributions of seven PM2 5 sources all decreased However, their contribution percentages varied from -11 0% (industrial processes) to 8 70% (secondary inorganic aerosol) Source contributions of PM2 5 transported from potential geographical regions showed reductions with mean values ranging from 0 22 to 4 36 μg m-3 However, increased contributions of firework burning, secondary inorganic aerosol, road dust and vehicle emissions from transboundary transport were observed This study highlighted the complex and nonlinear response of chemical compositions and sources of PM2 5 to air pollution control measures, suggesting the importance of regional-joint control

Zheng, Huang, et al. "Significant changes in the chemical compositions and sources of PM2. 5 in Wuhan since the city lockdown as COVID-19." Science of The Total Environment (2020): 140000.

Changes in U.S. air pollution during the COVID-19 pandemic

The COVID-19 global pandemic has likely affected air quality due to extreme changes in human behavior. We assessed air quality during the COVID-19 pandemic for fine particulate matter (PM2.5) and nitrogen dioxide (NO2) in the continental United States from January 8th-April 21st in 2017–2020. We considered pollution during the COVID-19 period (March 13–April 21st) and the pre-COVID-19 period (January 8th-March 12th) with 2020 representing 'current' data and 2017–2019 representing 'historical' data. County-level pollution concentrations were compared between historical versus current periods, and counties were stratified by institution of early or late non-essential business closures. Statistically significant NO2 declines were observed during the current COVID-19 period compared to historical data: a 25.5% reduction with absolute decrease of 4.8 ppb. PM2.5 also showed decreases during the COVID-19 period, and the reduction is statistically significant in urban counties and counties from states instituting early non-essential business closures. Understanding how air pollution is affected during COVID-19 pandemic will provide important clues regarding health effects and control of emissions. Further investigation is warranted to link this finding with health implications.

Berman, Jesse D., and Keita Ebisu. "Changes in US air pollution during the COVID-19 pandemic." Science of The Total Environment (2020): 139864.

21-Day Lockdown in India Dramatically Reduced Air Pollution Indices in Lucknow and New Delhi, India

In December 2019, the outbreak of viral disease labeled as Novel Coronavirus started in Wuhan, China, which later came to be known as Covid-19. The disease has spread in almost every part of the world and has been declared a global pandemic in March 2020 by World Health Organization (WHO). The corona

virus outbreak has emerged as one of the deadliest pandemics of all time in human history. The ongoing pandemic of COVID-19 has forced several countries of the world to observe complete lockdown forcing people to live in their homes. India also faced the phase of total lockdown for 21 days (in first phase) to avoid the spread of coronavirus to the maximum possible extent. This lockdown impacted the pollution levels of environment and improved air and water quality in the short span owing to very less human activities. The present work scientifically analyzed the available data for primary air pollutants (PM2.5, NO2, SO2 and CO) from two major Indian cities, Lucknow and New Delhi. The analysis was based on air quality data for before lockdown and after lockdown (first phase of 21 days) periods of 21 days each. The results showed significant decline in the studied air pollution indices and demonstrated improvement of air quality in both the cities. The major impact was seen in the levels of PM2.5, NO2 and CO. The levels of SO2 showed less significant decline during the lockdown period. The results are presented with future perspectives to mitigate air pollution in near future by adopting the short and periodical lockdown as a tool.

Srivastava, Sudhakar, et al. "21-Day Lockdown in India Dramatically Reduced Air Pollution Indices in Lucknow and New Delhi, India." Bulletin of Environmental Contamination and Toxicology (2020): 1.

COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain)

During the months of March and April 2020 we witnessed the largest-scale experiment in history in terms of air quality in cities. Any prediction of this experiment's results may be obvious to science, as it was totally expected, the air quality has improved substantially. Simply stated, it comes as no surprise. The lockdown has made it possible to quantify the limit of decrease in pollution in light of this drastic reduction in traffic, in Madrid and Barcelona showed a significant decrease of the order of 75%. In the case of Spain's two largest cities, the reductions of NO2 concentrations were 62% and 50%, respectively. Hourly measurements were obtained from 24 and 9 air quality stations from the monitoring networks during the month of March 2020. These results allow us to see the limits that can be achieved by implementing low emission zones (LEZ), as well as the amount of contamination that must be eliminated, which in the cases of Madrid and Barcelona, represent 55%. This value defines the levels of effort and scope of actions to be taken in order to ensure that both cities achieve a clean and healthy atmosphere in terms of NO2.

Baldasano, José M. "COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain)." Science of The Total Environment (2020): 140353.

SARS-CoV-2 pandemic lockdown: Effects on air quality in the industrialized Gujarat state of India

Two weeks after the world health organization described the novel coronavirus (SARS-CoV-2) outbreak as pandemic, the Indian government implemented lockdown of industrial activities and traffic flows across the entire nation between March 24 and May 31, 2020. In this paper, we estimated the improvements achieved in air quality during the lockdown period (March 24, 2020 and April 20, 2020) compared to the pre-lockdown (January 1, 2020 and March 23, 2020) by analyzing PM2.5, PM10, SO4, CO, NO2 and O3 data from nine different air quality monitoring stations distributed across four different zones of the industrialized Gujarat state of western Indian. The Central Pollution Control Board (CPCB)-Air Quality Index (AQI) illustrated better air qualities during the lockdown with higher improvements in the zones 2 (Ahmedabad and Gandhinagar) and 3 (Jamnagar and Rajkot), and moderate improvements in the zones 1 (Surat, Ankleshwar and Vadodra) and 4 (Bhuj and Palanpur). The concentrations of PM2.5, PM10, and NO2 were reduced by 38–78%, 32–80% and 30–84%, respectively. Functioning of the power plants possibly led to less reduction in CO (3–55%) and the declined emission of NO helped to improve O3 (16–48%) contents. We observed an overall improvement of 58% in AQI for the first four months of 2020 compared to the same interval of previous year. This positive outcome resulted from the lockdown restrictions might help to modify the existing environmental policies of the region.

Selvam, S., et al. "SARS-CoV-2 pandemic lockdown: Effects on air quality in the industrialized Gujarat state of India."

Science of The Total Environment (2020): 140391.

Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China

The absence of motor vehicle traffic and suspended manufacturing during the COVID-19 pandemic in China produced a unique experiment to assess the efficiency of air pollution mitigation. Up to 90% reduction of certain emissions during the city-lockdown period can be identified from satellite and ground-based observations. Unexpectedly, extreme particulate matter levels simultaneously occurred in northern China. Our synergistic observation analyses and model simulations show that anomalously high humidity promoted aerosol heterogeneous chemistry, along with stagnant airflow and uninterrupted emissions from power plants and petrochemical facilities, contributing to severe haze formation. Also, because of non-linear production chemistry and titration of ozone in winter, reduced nitrogen oxides resulted in ozone enhancement in urban areas, further increasing the atmospheric oxidizing capacity and facilitating secondary aerosol formation.

Le, Tianhao, et al. "Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China." Science (2020).

Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China

To control the spread of the 2019 novel coronavirus (COVID-19), China imposed nationwide restrictions on the movement of its population (lockdown) after the Chinese New Year of 2020, leading to large reductions in economic activities and associated emissions. Despite such large decreases in primary pollution, there were nonetheless several periods of heavy haze pollution in East China, raising questions about the well-established relationship between human activities and air quality. Here, using comprehensive measurements and modeling, we show the haze during the COVID lockdown were driven by enhancements of secondary pollution. In particular, large decreases in NOx emissions from transportation increased ozone and nighttime NO3 radical formation, and these increases in atmospheric oxidizing capacity in turn facilitated the formation of secondary particulate matter. Our results, afforded by the tragic natural experiment of the COVID-19 pandemic, indicate that haze mitigation depends upon a coordinated and balanced strategy for controlling multiple pollutants.

Huang, Xin, et al. "Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China." (2020).

Indirect impact of COVID-19 on environment: A brief study in Indian context

Worldwide spread of COVID-19 in a quite short time has brought a dramatic decrease in industrial activities, road traffic and tourism. Restricted human interaction with nature during this crisis time has appeared as a blessing for nature and environment. Reports from all over the world are indicating that after the outbreak of COVID-19, environmental conditions including air quality and water quality in rivers are improving and wildlife is blooming. India has always been a hub of pollution with huge population, heavy traffics and polluting industries leading to high air quality index (AQI) values in all major cities. But after declaration of lockdown due to COVID-19, quality of air has started to improve and all other environmental parameters such as water quality in rivers have started giving a positive sign towards restoring. This paper provides evidence-based insight into improvement of air quality and environment during pre and post lockdown of this pandemic situation. An attempt has been made to visualize the improvement in the air quality using tools like satellite images of Indian atmosphere, results of onsite real-time monitoring at specific locations (Ghaziabad-highest polluting city of India) and Air quality index (AQI) calculated by central pollution control board of India.

Lokhandwala, Snehal, and Pratibha Gautam. "Indirect impact of COVID-19 on Environment: A brief study in Indian Context." Environmental Research (2020): 109807.

Satellite-detected tropospheric nitrogen dioxide and spread of SARS-CoV-2 infection in Northern Italy

Following the outbreak of Severe Acute Respiratory Syndrome CoronaVirus 2 (SARS-CoV-2) last December 2019 in China, Italy was the first European country to be severely affected, with the first local case diagnosed on 20 February 2020. The virus spread quickly, particularly in the North of Italy, with three regions (Lombardy, Veneto and Emilia-Romagna) being the most severely affected. These three regions accounted for >80% of SARS-CoV-2 positive cases when the tight lockdown was established (March 8). These regions include one of Europe's areas of heaviest air pollution, the Po valley. Air pollution has been recently proposed as a possible risk factor of SARS-CoV-2 infection, due to its adverse effect on immunity and to the possibility that polluted air may even carry the virus. We investigated the association between air pollution and subsequent spread of the SARS-CoV-2 infection within these regions. We collected NO2 tropospheric levels using satellite data available at the European Space Agency before the lockdown. Using a multivariable restricted cubic spline regression model, we compared NO2 levels with SARS-CoV-2 infection prevalence rate at different time points after the lockdown, namely March 8, 22 and April 5, in the 28 provinces of Lombardy, Veneto and Emilia-Romagna. We found little association of NO2 levels with SARS-CoV-2 prevalence up to about 130 µmol/m2, while a positive association was evident at higher levels at each time point. Notwithstanding the limitations of the use of aggregated data, these findings lend some support to the hypothesis that high levels of air pollution may favor the spread of the SARS-CoV-2 infection.

Filippini, Tommaso, et al. "Satellite-detected tropospheric nitrogen dioxide and spread of SARS-CoV-2 infection in Northern Italy." Science of The Total Environment (2020): 140278.

Impact of lockdown measures during COVID-19 on air quality– A case study of India

A novel infectious coronavirus disease (COVID-19) identified in late 2019 has now been labelled as a global pandemic by World Health Organization (WHO). The COVID-19 outbreak has shown some positive impacts on the natural environment. In present work, India is taken as a case study to evaluate the effect of lockdown on air quality of three Indian cities. The variation in concentration of key air pollutants including PM10, PM2.5, NO2, SO2 and O3 during two phases, pre-lockdown and post-lockdown phases, was analysed. The concentration of PM10, PM2.5, NO2 and SO2 reduced by 55%, 49%, 60% and 19%, and 44%, 37%, 78% and 39% for Delhi and Mumbai, respectively, during post-lockdown phase. Overall, the findings in present study may provide confidence to the stakeholders involved in air quality policy development that a significant improvement in air quality can be achieved in future if better pollution control plans are strictly executed.

Kumari, Pratima, and Durga Toshniwal. "Impact of lockdown measures during COVID-19 on air quality–A case study of India." International Journal of Environmental Health Research (2020): 1-8.

Unexpected rise of ozone in urban and rural areas, and sulfur dioxide in rural areas during the coronavirus city lockdown in Hangzhou, China: implications for air quality

The outbreak of coronavirus named COVID-19, initially identified in Wuhan, China in December 2019, has spread rapidly at the global scale. Most countries have rapidly stopped almost all activities including industry, services and transportation of goods and people, thus decreasing air pollution in an unprecedented way, and providing a unique opportunity to study air pollutants. While satellite data have

provided visual evidence for the global reduction in air pollution such as nitrogen dioxide (NO2) worldwide, precise and quantitative information is missing at the local scale. Here we studied changes in particulate matter (PM2.5, PM10), carbon monoxide (CO), NO2, sulfur dioxide (SO2) and ozone (O3) at 10 urban sites in Hangzhou, a city of 7.03 million inhabitants, and at 1 rural site, before city lockdown, January 1–23, during city lockdown, January 24-February 15, and during resumption, February 16–28, in 2020. Results show that city lockdown induced a sharp decrease in PM2.5, PM10, CO, and NO2 concentrations at both urban and rural sites. The NO2 decrease is explained by reduction in traffic emissions in the urban areas, and by lower regional transport in rural areas during lockdown, as expected. SO2 concentrations decreased from 6.3 to 5.3 µg m-3 in the city, but increased surprisingly from 4.7 to 5.8 µg m-3 at the rural site: this increase is attributed both to higher coal consumption for heating and emissions from traditional fireworks of the Spring Eve and Lantern Festivals during lockdown. Unexpectedly, O3 concentrations increased by 145% from 24.6 to 60.6 µg m-3 in the urban area, and from 42.0 to 62.9 µg m-3 in the rural area during the lockdown. This finding is explained by the weakening of chemical titration of O3 by NO due to reductions of NOx fresh emissions during the non-photochemical reaction period from 20:00 PM to 9:00 AM (local time). During the lockdown, compared to the same period in 2019, the daily average concentrations in the city decreased by 42.7% for PM2.5, 47.9% for PM10, 28.6% for SO2, 22.3% for CO and 58.4% for NO2, which is obviously explained by the absence of city activities. Overall, we observed not only the expected reduction in some atmospheric pollutants (PM, SO2, CO, NO2), but also unexpected increases in SO2 in the rural areas and of ozone (O3) in both urban and rural areas, the latter being paradoxically due to the reduction in nitrogen oxide levels. In other words, the city lockdown has improved air quality by reducing PM2.5, PM10, CO, and NO2, but has also decreased air quality by augmenting O3 and SO2.

Wang, Liqiang, et al. "Unexpected rise of ozone in urban and rural areas, and sulfur dioxide in rural areas during the coronavirus city lockdown in Hangzhou, China: implications for air quality." Environmental Chemistry Letters (2020): 1-11.

Impact of lockdown measures to combat Covid-19 on air quality over western Europe

Recent studies based on observations have shown the impact of lockdown measures taken in various European countries to contain the Covid-19 pandemic on air quality. However, these studies are often limited to compare situations without and with lockdown measures, which correspond to different time periods and then under different meteorological conditions. We propose a modelling study with the WRF-CHIMERE modelling suite for March 2020, an approach allowing to compare atmospheric composition with and without lockdown measures without the biases of meteorological conditions. This study shows that the lockdown effect on atmospheric composition, in particular through massive traffic reductions, has been important for several short-lived atmospheric trace species, with a large reduction in NO2 concentrations, a lower reduction in Particulate Matter (PM) concentrations and a mitigated effect on ozone concentrations due to non-linear chemical effects.

Menut, Laurent, et al. "Impact of lockdown measures to combat Covid-19 on air quality over western Europe." Science of The Total Environment (2020): 140426.

Effects of Meteorological Conditions and Air Pollution on COVID-19 Transmission: Evidence From 219 Chinese Cities

The spatial distribution of the COVID-19 infection in China cannot be explained solely by geographical distance and regulatory stringency. In this research we investigate how meteorological conditions and air pollution, as concurring factors, impact COVID-19 transmission, using data on new confirmed cases from 219 prefecture cities from January 24 to February 29, 2020. Results revealed a kind of nonlinear dose-response relationship between temperature and coronavirus transmission. We also found that air pollution indicators are positively correlated with new confirmed cases, and the coronavirus further spreads by 5-7%

as the AQI increases by 10 units. Further analysis based on regional divisions revealed that in northern China the negative effects of rising temperature on COVID-19 is counteracted by aggravated air pollution. In the southern cities, the ambient temperature and air pollution have a negative interactive effect on COVID-19 transmission, implying that rising temperature restrains the facilitating effects of air pollution and that they jointly lead to a decrease in new confirmed cases. These results provide implications for the control and prevention of this disease and for the anticipation of another possible pandemic.

Zhang, Zhenbo, Ting Xue, and Xiaoyu Jin. "Effects of meteorological conditions and air pollution on COVID-19 transmission: Evidence from 219 Chinese cities." Science of The Total Environment (2020): 140244.

NOx Emission Reduction and Recovery during COVID-19 in East China

Since its first confirmed case at the end of 2019, COVID-19 has become a global pandemic in three months with more than 1.4 million confirmed cases worldwide, as of early April 2020. Quantifying the changes of pollutant emissions due to COVID-19 and associated governmental control measures is crucial to understand its impacts on economy, air pollution, and society. We used the WRF-GC model and the tropospheric NO2 column observations retrieved by the TROPOMI instrument to derive the top-down NOx emission change estimation between the three periods: P1 (January 1st to January 22nd, 2020), P2 (January 23rd, Wuhan lockdown, to February 9th, 2020), and P3 (February 10th, back-to-work day, to March 12th, 2020). We found that NOx emissions in East China averaged during P2 decreased by 50% compared to those averaged during P1. The NOx emissions averaged during P3 increased by 26% compared to those during P2. Most provinces in East China gradually regained some of their NOx emissions after February 10, the official back-to-work day, but NOx emissions in most provinces have not yet to return to their previous levels in early January. NOx emissions in Wuhan, the first epicenter of COVID-19, had no sign of emission recovering by March 12. A few provinces, such as Zhejiang and Shanxi, have recovered fast, with their averaged NOx emissions during P3 almost back to pre-lockdown levels.

Zhang, Ruixiong, et al. "NOx Emission Reduction and Recovery during COVID-19 in East China." Atmosphere 11.4 (2020): 433.

Statistical evaluation of selected air quality parameters influenced by COVID-19 lockdown

Air pollution has become a serious concern for its potential health hazard, however, often got less attention in developing countries, like Bangladesh. It is expected that worldwide lockdown due to COVID-19 widespread cause reduction in environmental pollution in particularly the air pollution: however, such changes have been different in different places. In Chittagong, a city scale lockdown came in force on 26 March 2020, a week after when first three cases of COVID-19 have been reported in Bangladesh. This study aims to statistically evaluate the effects of COVID-19 lockdown (26 March to 26 April 2020) on selected air quality pollutants and air quality index s. The daily average concentrations of air pollutants PM10, PM2.5, NO2, SO2 and CO of Chittagong city during COVID-19 lockdown were statistically evaluated and were compared with dry season data averaging over previous 8 years (2012 to 2019). During lockdown, except NO2, all other pollutants studied showed statistically significant decreasing trend. During the COVID-19 shutdown notable reduction of 40%, 32% and 13% compared to the daily mean concentrations of these previous dry season were seen for PM2.5, PM10 and NO2, respectively. The improvement in air quality index value was found as 26% in comparison to the previous dry season due to less human activities in COVID-19 shutdown. The factor analysis showed that AQI in Chittagong city is largely influenced by PM10 and PM2.5 during COVID-19 shutdown. The lesson learnt in this forced measure of lockdown is not surprising and unexpected. It is rather thought provoking for the decision makers to tradeoff the tangible air quality benefits with ongoing development strategies' that was often overlooked directly or indirectly.

Masum, M. H., and S. K. Pal. "Statistical evaluation of selected air quality parameters influenced by COVID-19

lockdown." Global Journal of Environmental Science and Management 6.Special Issue (Covid-19) (2020): 85-94.

Short-term exposure to ambient air quality of the most polluted Indian cities due to lockdown amid SARS-CoV-2

Air pollution has happened to be one of the mounting alarms to be concerned with in many Indian cities. COVID-19 epidemic endow with a unique opportunity to report the degree of air quality improvement due to the nationwide lockdown in 10 most polluted cities across the country. National Air Quality Index (NAQI) based on continuous monitoring records of seven criteria pollutants (i.e. common air pollutants with known health impacts e.g. PM10, PM2.5, CO, NO2, SO2, NH3 and O3) for a total of 59 stations across the cities, satellite image derived Aerosol Optical Depth (AOD) and few statistical tools are employed to derive the outcomes. NAQI results convey that 8 cities out of the 10 air quality restored to good to satisfactory category during the lockdown period. Within week+1 of the lockdown period, PM10 and PM2.5 concentrations have suppressed below the permissible limit in all cities. CO and NO2 have reduced to about -30% and -57% respectively during the lockdown period. Diurnal concentrations of PM10 and PM2.5 have dropped drastically on the very 4th day of lockdown and become consistent with minor hourly vacillation. In April 2020 the AOD amount was reduced to about 36% and 18% in contrast to April 2018 and April 2019 respectively. This add-on reporting of the possible recovery extent in air quality may help to guide alternative policy intervention in form of short term lockdown so as to testify whether this type of unconventional policy decisions may be put forward to attain a green environment. Because, despite numerous restoration plans, air pollution levels have risen unabated in these cities. However, detailed inventory needs to be focused on identifying the localized pollution hotspots (i.e. source contribution).

Mahato, Susanta, and Krishna Gopal Ghosh. "Short-term exposure to ambient air quality of the most polluted Indian cities due to lockdown amid SARS-CoV-2." Environmental Research (2020): 109835.

Air quality during the COVID-19: PM2.5 analysis in the 50 most polluted capital cities in the world

On December 31, 2019, the Chinese authorities reported to the World Health Organization (WHO) the outbreak of a new strain of coronavirus that causes a serious disease in the city of Wuhan, China. This outbreak was classified as SARS-CoV2 and is the cause of the COVID-19 disease. On March 11, 2020, the WHO declares it a Pandemic and today it is considered the greatest challenge in global health that humanity has faced since World War II and it is estimated that between 40 and 60% of the population worldwide will catch the virus. This has caused enormous challenges in countries around the world in social, economic, environmental and obviously health issues. These challenges are mainly due to the effects of the established quarantines in almost all capitals and major cities around the world, from Asia, Europe to America. However, these lockdown which began worldwide from January 23, have had a significant impact on the environment and on the air quality of cities as recently reported by NASA (National Aeronautics and Space Administration) and ESA (European Space Agency), with reductions according to them of up to 30% in some of the epicenters such as the case of Wuhan. Knowing that air pollution causes approximately 29% of lung cancer deaths, 43% of COPD deaths, and 25% of ischemic heart disease deaths, it is important to know the effects of quarantines in cities regarding air quality to take measures that favor populations and urban ecosystems when the emergency ends. Therefore, this paper describes the behavior of PM2.5 emissions particulate matter from the 50 most polluted capital cities in the world according to the WHO, measured before-after the start of the quarantine. Likewise, the impact at the local and global level of this emissions behavior, which averaged 12% of PM2.5 decrease in these cities.

Rodríguez-Urrego, Daniella, and Leonardo Rodríguez-Urrego. "Air quality during the COVID-19: PM2. 5 analysis in the 50 most polluted capital cities in the world." Environmental Pollution (2020): 115042.

COVID-19 and air pollution: A dangerous association?

In late 2019, a new infectious disease (COVID-19) was identified in Wuhan, China, which has now turned into a global pandemic. Countries around the world have implemented some type of blockade to lessen their infection and mitigate it. The blockade due to COVID-19 has drastic effects on the social and economic fronts. However, recent data released by the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), Copernicus Sentinel-5P Tropomi Instrument and Center for Research on Energy and Clean Air (CREA) indicate that the pollution in some of the epicenters of COVID-19, such as Wuhan, Italy, Spain, USA, and Brazil, reduced by up to 30%. This study compiled the environmental data released by these centers and discussed the impact of the COVID-19 pandemic on environmental pollution.

Urrutia-Pereira, M., C. A. Mello-da-Silva, and D. Solé. "COVID-19 and air pollution: A dangerous association?." Allergologia et Immunopathologia (2020).

Air pollution in Ontario, Canada during the COVID-19 State of Emergency

In March of 2020, the province of Ontario declared a State of Emergency (SOE) to reduce the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the coronavirus disease (COVID-19). This disruption to the economy provided an opportunity to measure change in air pollution when the population spends more time at home with fewer trips. Hourly air pollution observations were obtained for fine particulate matter, nitrogen dioxide, nitrogen oxides and ozone from the Ontario air monitoring network for 2020 and the previous five years. The analysis is focused on a five-week period during the SOE with a previous five-week period used as a control. Fine particulate matter did not show any significant reductions during the SOE. Ozone concentrations at 12 of the 32 monitors were lower than any of the previous five-years; however, four locations were above average. Average ozone concentrations were 1 ppb lower during the SOE, but this ranged at individual monitors from 1.5 ppb above to 4.2 ppb below long-term conditions. Nitrogen dioxide and nitrogen oxides demonstrated a reduction across Ontario, and both pollutants displayed their lowest concentrations for 22 of 29 monitors. Individual monitors ranged from 1 ppb (nitrogen dioxide) and 5 ppb (nitrogen oxides) above average to 4.5 (nitrogen dioxide) and 7.1 ppb (nitrogen oxides) below average. Overall, both nitrogen dioxide and nitrogen oxides demonstrated a reduction across Ontario in response to the COVID-19 SOE, ozone concentrations suggested a possible reduction, and fine particulate matter has not varied from historic concentrations.

Adams, Matthew D. "Air pollution in Ontario, Canada during the COVID-19 State of Emergency." Science of The Total Environment (2020): 140516.

Effect of lockdown due to SARS COVID-19 on aerosol optical depth (AOD) over urban and mining regions in India

The Severe Acute Respiratory Syndrome-COronaVIrus Diseases 2019 (SARS-COVID-19) pandemic has posed a serious threat to human health (death) and substantial economic losses across the globe. It was however presumed that extreme preventive measures of entire lockdown in India might have reduced the air pollution level and therefore decreased the aerosol optical depth (AOD). The Moderate Resolution Imaging Spectroradiometer (MODIS)-based Multi-angle Implementation of Atmospheric Correction (MAIAC) daily AOD product was deployed to investigate the change in AOD level during lockdown phases across the Indian Territory as compared to the long-term mean AOD level (2000–2019) of the same periods. The key findings of the study revealed that AOD level over the Indian Territory is greatly reduced (~45%) during the lockdown periods as compared to the long-term mean AOD level (2000–2019). Furthermore, a noteworthy negative AOD anomaly (~6 to 37%) was observed across the four metropolitan cities in India during the

entire lockdown period (25th March to 15th May 2020). However, coal mining regions of the various coalfields in India showed a positive anomaly (~+11 to 40%) during the lockdown periods due to ongoing mining operations. In a nutshell, the study results indicated a huge drop in the AOD level over Indian Territory during lockdown periods. It is expected that the pandemic can influence some policy decisions to propose air pollution control methods. Lockdown events possibly may play a crucial role as a potential solution for air pollution abatement in the future. It may not be uncommon in future when the governments may implement deliberately selective lockdowns at pollution hotspots to control the pollution level.

Ranjan, Avinash Kumar, A. K. Patra, and A. K. Gorai. "Effect of lockdown due to SARS COVID-19 on aerosol optical depth (AOD) over urban and mining regions in India." Science of The Total Environment (2020): 141024.

Nonuniform impacts of COVID-19 lockdown on air quality over the United States

Most of the state governments in United States (U.S.) issued lockdown or business restrictions amid the COVID-19 pandemic in March 2020, which created a unique opportunity to evaluate the air quality response to reduced economic activities. Data acquired from 28 long-term air quality stations across the U.S. revealed widespread but nonuniform reductions of nitrogen dioxide (NO2) and carbon monoxide (CO) during the first phase of lockdown (March 15–April 25, 2020) relative to a pre-lockdown reference period and historical baselines established in 2017–2019. The reductions, up to 49% for NO2 and 37% for CO, are statistically significant at two thirds of the sites and tend to increase with local population density. Significant reductions of particulate matter (PM2.5 and PM10) only occurred in the Northeast and California/Nevada metropolises where NO2 declined the most, while the changes in ozone (O3) were mixed and relatively minor. These findings are consistent with lower transportation and utility demands that dominate NO2 and CO emissions, especially in major urban areas, due to the lockdown. This study provides an insight into potential public health benefits with more aggressive air quality management, which should be factored into strategies to reopen the U.S. and global economy.

Chen, L-W. Antony, et al. "Nonuniform impacts of COVID-19 lockdown on air quality over the United States." Science of The Total Environment (2020): 141105.

Reductions in mortality resulting from reduced air pollution levels due to COVID-19 mitigation measures

To control the novel coronavirus disease (COVID-19) outbreak, state and local governments in the United States have implemented several mitigation efforts that resulted in lower emissions of traffic-related air pollutants. This study examined the impacts of COVID-19 mitigation measures on air pollution levels and the subsequent reductions in mortality for urban areas in 10 US states and the District of Columbia. We calculated changes in levels of particulate matter with aerodynamic diameter no larger than 2.5 μm (PM2.5) during mitigation period versus the baseline period (pre-mitigation measure) using the difference-in-difference approach and the estimated avoided total and cause-specific mortality attributable to these changes in PM2.5 by state and district. We found that PM2.5 concentration during the mitigation period decreased for most states (except for 3 states) and the capital. Decreases of average PM2.5 concentration ranged from 0.25 μg/m3 (4.3%) in Maryland to 4.20 μg/m3 (45.1%) in California. On average, PM2.5 levels across 7 states and the capital reduced by 12.8%. We estimated that PM2.5 reduction during the mitigation period lowered air pollution-related total and cause-specific deaths. An estimated 483 (95% CI: 307, 665) PM2.5-related deaths was avoided in the urban areas of California. Our findings have implications for the effects of mitigation efforts and provide insight into the mortality reductions can be achieved from reduced air pollution levels.

Son, Ji-Young, et al. "Reductions in mortality resulting from reduced air pollution levels due to COVID-19 mitigation

measures." Science of The Total Environment (2020): 141012.

Reductions in traffic-related black carbon and ultrafine particle number concentrations in an urban neighborhood during the COVID-19 pandemic

We investigated changes in traffic-related air pollutant concentrations in an urban area during the COVID-19 pandemic. The study area was in a mixed commercial-residential neighborhood in Somerville (MA, USA), where traffic is the dominant source of air pollution. Measurements were conducted between March 27 and May 14, 2020, coinciding with a dramatic reduction in traffic (71% drop in car and 46% drop in truck traffic) due to business shutdowns and a statewide stay-at-home advisory. Indicators of fresh vehicular emissions (ultrafine particle number concentration [PNC] and black carbon [BC]) were measured with a mobile monitoring platform on an interstate highway and major and minor roadways. Depending on road class, median PNC and BC contributions from traffic were 60–68% and 22–46% lower, respectively, during the lockdown compared to pre-pandemic conditions. A higher BC:PNC concentration ratio was observed during the lockdown period perhaps indicative of the higher fraction of diesel vehicles in the fleet during the lockdown. Overall, the scale of reductions in ultrafine particle and BC concentrations was commensurate with the reductions in traffic. This natural experiment allowed us to quantify the direct impacts of reductions in traffic emissions on neighborhood-scale air quality, which are not captured by the regional regulatory-monitoring network. Results underscore the importance of measurements of appropriate proxies for traffic emissions at relevant spatial scales. Our results are also useful for exposure analysts, and city, and regional planners evaluating traffic-related air pollution impact mitigation strategies.

Hudda, Neelakshi, et al. "Reductions in traffic-related black carbon and ultrafine particle number concentrations in an urban neighborhood during the COVID-19 pandemic." Science of The Total Environment (2020): 140931.

Temporary reduction in fine particulate matter due to ‘anthropogenic emissions switch-off’ during COVID-19 lockdown in Indian cities

The COVID-19 pandemic elicited a global response to limit associated mortality, with social distancing and lockdowns being imposed. In India, human activities were restricted from late March 2020. This ‘anthropogenic emissions switch-off’ presented an opportunity to investigate impacts of COVID-19 mitigation measures on ambient air quality in five Indian cities (Chennai, Delhi, Hyderabad, Kolkata, and Mumbai), using in-situ measurements from 2015 to 2020. For each year, we isolated, analysed and compared fine particulate matter (PM2.5) concentration data from 25 March to 11 May, to elucidate the effects of the lockdown. Like other global cities, we observed substantial reductions in PM2.5 concentrations, from 19 to 43% (Chennai), 41–53 % (Delhi), 26–54 % (Hyderabad), 24–36 % (Kolkata), and 10–39 % (Mumbai). Generally, cities with larger traffic volumes showed greater reductions. Aerosol loading decreased by 29 % (Chennai), 11 % (Delhi), 4% (Kolkata), and 1% (Mumbai) against 2019 data. Health and related economic impact assessments indicated 630 prevented premature deaths during lockdown across all five cities, valued at 0.69 billion USD. Improvements in air quality may be considered a temporary lockdown benefit as revitalising the economy could reverse this trend. Regulatory bodies must closely monitor air quality levels, which currently offer a baseline for future mitigation plans.

Kumar, Prashant, et al. "Temporary reduction in fine particulate matter due to ‘anthropogenic emissions switch-off’during COVID-19 lockdown in Indian cities." Sustainable Cities and Society (2020): 102382.

Changes in air pollution during COVID-19 lockdown in Spain: a multi-city study

The COVID-19 pandemic has escalated into one of the largest crises of the 21st Century. The new SARS-CoV-2 coronavirus, responsible for COVID-19, has spread rapidly all around the world. The Spanish

Government was forced to declare a nationwide lockdown in view of the rapidly spreading virus and high mortality rate in the nation. This study investigated the impact of short-term lockdown during the period from March 15th to April 12th 2020 on the atmospheric levels of CO, SO2, PM10, O3, and NO2 over 11 representative Spanish cities. The possible influence of several meteorological factors (temperature, precipitation, wind, sunlight hours, minimum and maximum pressure) on the pollutants' levels were also considered. The results obtained show that the 4-week lockdown had significant impact on reducing the atmospheric levels of NO2 in all cities except for the small city of Santander as well as CO, SO2, and PM10 in some cities, but resulted in increase of O3 level.

Briz-Redón, Álvaro, Carolina Belenguer-Sapiña, and Ángel Serrano-Aroca. "Changes in air pollution during COVID-19 lockdown in Spain: a multi-city study." Journal of Environmental Sciences (2020).

Changes in air pollution levels after COVID-19 outbreak in Korea

In order to control the spread of COVID-19, social distancing measures were implemented in many countries. This study investigated changes in air pollution during the social distancing after the COVID-19 outbreak in Korea. Ambient PM2.5, PM10, NO2, and CO that are particularly related to industrial activities and traffic were reduced during the social distancing in response to the COVID-19 outbreak. In March 2020, immediately after social distancing, mean levels of PM2.5, PM10, NO2, and CO decreased nationwide from last year's mean levels by 16.98 μg/m3, 21.61 μg/m3, 4.16 ppb, and 0.09 ppm, respectively (p-value for the year-to-year difference < 0.001, =0.001, =0.008, <0.001), a decrease by 45.45%, 35.56%, 20.41%, and 17.33%, respectively. Changes in ambient O3 or SO2 were not observed to be attributable to social distancing. Our findings, that such effort for a short period of time resulted in a significant reduction in air pollution, may point toward reducing air pollution as a public health problem in a more sustainable post-COVID-19 world.

Ju, Min Jae, Jaehyun Oh, and Yoon-Hyeong Choi. "Changes in air pollution levels after COVID-19 outbreak in Korea." Science of The Total Environment (2020): 141521.

Impact of the COVID-19 pandemic and control measures on air quality and aerosol light absorption in Southwestern China

China has been performing nationwide social lockdown by releasing the Level 1 response to major public health emergencies (RMPHE) to struggle against the COVID-19 (SARS-CoV-2) outbreak since late January 2020. During the Level 1 RMPHE, social production and public transport were maintained at minimal levels, and residents stayed in and worked from home. The universal impact of anthropogenic activities on air pollution can be evaluated by comparing it with air quality under such extreme conditions. We investigated the concentration of both gaseous and particulate pollutants and aerosol light absorption at different levels of (RMPHE) in an urban area of southwestern China. During the lockdown, PM2.5, PM10, SO2, NOx, and BC decreased by 30–50%, compared to the pre-Level 1 RMPHE period. Meanwhile, the decrease of NOx caused the rise of O3 by up to 2.3 times due to the volatile organic compounds (VOCs) limitation. The aerosol light absorption coefficient at multiple wavelengths decreased by 50%, and AAE decreased by 20% during the Level 1 RMPHE. BrC played essential roles in light absorption after the RMPHE was announced, accounting for 54.0% of the aerosol absorption coefficient at 370 nm. Moreover, the lockdown down-weighted the fraction of fossil fuel in BC concentrations to 0.43 (minima). This study characterizes air pollution at the most basic level and can provide policymakers with references for the “baseline.”

Chen, Yang, et al. "Impact of the COVID-19 pandemic and control measures on air quality and aerosol light absorption in Southwestern China." Science of The Total Environment (2020): 141419.

Evidence-Based Considerations Exploring Relations between SARS-CoV-2 Pandemic and Air Pollution: Involvement of PM2.5-Mediated Up-Regulation of the Viral Receptor ACE-2

The COVID-19/SARS-CoV-2 pandemic struck health, social and economic systems worldwide, and represents an open challenge for scientists —coping with the high inter-individual variability of COVID-19, and for policy makers —coping with the responsibility to understand environmental factors affecting its severity across different geographical areas. Air pollution has been warned of as a modifiable factor contributing to differential SARS-CoV-2 spread but the biological mechanisms underlying the phenomenon are still unknown. Air quality and COVID-19 epidemiological data from 110 Italian provinces were studied by correlation analysis, to evaluate the association between particulate matter (PM)2.5 concentrations and incidence, mortality rate and case fatality risk of COVID-19 in the period 20 February–31 March 2020. Bioinformatic analysis of the DNA sequence encoding the SARS-CoV-2 cell receptor angiotensin-converting enzyme 2 (ACE-2) was performed to identify consensus motifs for transcription factors mediating cellular response to pollutant insult. Positive correlations between PM2.5 levels and the incidence ($r = 0.67$, $p < 0.0001$), the mortality rate ($r = 0.65$, $p < 0.0001$) and the case fatality rate ($r = 0.7$, $p < 0.0001$) of COVID-19 were found. The bioinformatic analysis of the ACE-2 gene identified nine putative consensus motifs for the aryl hydrocarbon receptor (AHR). Our results confirm the supposed link between air pollution and the rate and outcome of SARS-CoV-2 infection and support the hypothesis that pollution-induced over-expression of ACE-2 on human airways may favor SARS-CoV-2 infectivity.

Borro, Marina, et al. "Evidence-Based Considerations Exploring Relations between SARS-CoV-2 Pandemic and Air Pollution: Involvement of PM2. 5-Mediated Up-Regulation of the Viral Receptor ACE-2." International Journal of Environmental Research and Public Health 17.15 (2020): 5573.

The legacy of COVID-19: lessons and challenges for city-scale air quality management in the UK

The lockdown enforced by the UK Government to prevent the spread of the SARS-CoV-2 virus has led to an unparalleled reduction in traffic volumes and significant drop in nitrogen dioxide concentrations in most cities, although the picture emerging from residential emissions of particulate matter (PM10 and PM2.5) is more complex. The scale and degree of the intervention have exposed the level of change required to reduce pollution. Learning from the COVID-19 crisis, we identify three challenges that must be overcome to improve air quality in cities. First, what measures would be effective that balance civil liberties with enforcement action on air pollution? Second, how do we consolidate the cultural change needed to retain and normalise the social practices driving the observed pollution reduction? Third, how do we tackle these challenges in a way that breaks current patterns of socio-economic, health and environmental inequality?

De Vito, Laura, et al. "The legacy of COVID-19: lessons and challenges for city-scale air quality management in the UK." Cities & Health (2020): 1-4.

COVID-19 lockdowns cause global air pollution declines

The lockdown response to coronavirus disease 2019 (COVID-19) has caused an unprecedented reduction in global economic and transport activity. We test the hypothesis that this has reduced tropospheric and ground-level air pollution concentrations, using satellite data and a network of >10,000 air quality stations. After accounting for the effects of meteorological variability, we find declines in the population-weighted concentration of ground-level nitrogen dioxide (NO_2: 60% with 95% CI 48 to 72%), and fine particulate matter ($PM_{2.5}$: 31%; 95% CI: 17 to 45%), with marginal increases in ozone (O_3: 4%; 95% CI: −2 to 10%) in 34 countries during lockdown dates up until 15 May. Except for ozone, satellite measurements of the troposphere indicate much smaller reductions, highlighting the spatial variability of pollutant anomalies attributable to complex NO_x chemistry and long-distance transport of fine particulate matter with a diameter less than 2.5 µm ($PM_{2.5}$). By leveraging Google and Apple mobility data, we find empirical

evidence for a link between global vehicle transportation declines and the reduction of ambient NO_2 exposure. While the state of global lockdown is not sustainable, these findings allude to the potential for mitigating public health risk by reducing "business as usual" air pollutant emissions from economic activities.

Venter, Zander S., et al. "COVID-19 lockdowns cause global air pollution declines." Proceedings of the National Academy of Sciences (2020).

Impacts of the COVID-19 responses on traffic-related air pollution in a Northwestern US city

This study evaluates the COVID-19 impacts on traffic-related air pollution, including ultrafine particles (UFPs), PM2.5, black carbon (BC), NO, NO2, NOx, and CO in a Northwestern US city. Hourly traffic, air pollutants, and meteorological data on/near a major freeway in the downtown of Seattle, Washington, were collected for five weeks before and ten weeks after the Washington Stay Home Order (SHO) was enacted, respectively (February 17–May 31, 2020). The pollutants between pre- and post-SHO periods were compared, and their differences were statistically tested. Besides, first-order multivariate autoregressive (MAR(1)) models were developed to reveal the impacts specific to the change of traffic due to the COVID-19 responses while controlling for meteorological conditions. Results indicate that compared with those in the post-SHO period, the median traffic volume and road occupancy decreased by 37% and 52%, respectively. As for pollutants, the median BC and PM2.5 levels significantly decreased by 25% and 33%, relatively, while NO, NO2, NOx, and CO decreased by 33%, 29%, 30%, and 17%, respectively. In contrast, neither size-resolved UFPs nor total UFPs showed significant changes between the two periods, although larger particles (≥115.5 nm) decreased by 4–29%. Additionally, significant differences were found in meteorological conditions between the two periods. Based on the MAR(1) models, controlling for meteorological conditions, the COVID-19 responses were associated with significant decreases in median levels of traffic-related pollutants including 11.5–154.0 nm particles (ranging from -3% [95% confidence interval (CI): -1%, -4%] to -12% [95% CI: -10%, -14%]), total UFPs (-7% [95% CI: -5%, -8%]), BC (-6% [95% CI: -5%, -7%]), PM2.5 (-2% [95% CI: -1%, -3%]), NO, NO2, NOx (ranging from -3% [95% CI: -2%, -4%] to -10% [95% CI: -18%, -12%]), and CO (-4% [95% CI, -3%, -5%]). These findings illustrate that the conclusion of the COVID-19 impacts on urban traffic-related air pollutant levels could be completely different in scenarios whether meteorology was adjusted for or not. Fully adjusting for meteorology, this study shows that the COVID-19 responses were associated with much more reductions in traffic-related UFPs than PM2.5 in the Seattle region, in contrast to the reverse trend from the direct empirical data comparison.

Xiang, Jianbang, et al. "Impacts of the COVID-19 responses on traffic-related air pollution in a Northwestern US city." Science of The Total Environment (2020): 141325.

Significant decrease of lightning activities during COVID-19 lockdown period over Kolkata megacity in India

The outbreak of COVID-19 has now created the largest pandemic and the World health organization (WHO) has declared social distancing as the key precaution to confront such type of infections. Most of the countries have taken protective measures by the nationwide lockdown. The purpose of this study is to understand the effect of lockdown on air pollutants and to analyze pre-monsoon (April and May) cloud-to-ground and inter-cloud lightning activity in relation to air pollutants i.e. suspended Particulate matter (PM10), Nitrogen dioxides (NO2) Sulfur dioxide (SO2), Ozone (O3) and Aerosol concentration (AC) in a polluted tropical urban megacities like Kolkata. After the strict lockdown the pollutants rate has reduced by more than 40% from the pre-lockdown period in the Kolkata megacity. So, decreases of PM10, NO2, SO2, O3 and AC have a greater effect on cloud lightning flashes in the pre-monsoon period. In the previous year (2019), the pre-monsoon average result shows a strong positive relation between the lightning and air

pollutants; PM10 (R2 = 0.63), NO2 (R2 = 0.63), SO2 (R2 = 0.76), O3 (R2 = 0.68) and AC (R2 = 0.83). The association was relatively low during the lock-down period (pre-monsoon 2020) and the R2 values were 0.62, 0.60, 0.71, 0.64 and 0.80 respectively. Another thing is that the pre-monsoon (2020) lightning strikes decreased by 49.16% compared to the average of previous years (2010 to 2019). The overall study shows that the reduction of surface pollution in the thunderstorm environment is strongly related to the reduction of lightning activity where PM10 and AC are the key pollutants in the Kolkata megacity.

Chowdhuri, Indrajit, et al. "Significant decrease of lightning activities during COVID-19 lockdown period over Kolkata megacity in India." Science of The Total Environment (2020): 141321.

Unprecedented Temporary Reduction in Global Air Pollution Associated with COVID-19 Forced Confinement: A Continental and City Scale Analysis

Shortly after the outbreak of the novel infectious disease (COVID-19) started at the end of 2019, it turned into a global pandemic, which caused the lockdown of many countries across the world. Various strict measures were adopted to reduce anthropogenic activities in order to prevent further spread and infection of the disease. In this study, we utilized continental scale remotely sensed data along with city scale in situ air quality observations for 2020 as well as data from the baseline period (2015–2019) to provide an early insight on air pollution changes in response to the COVID-19 pandemic lockdown, by combining both continental and city scales. For the continental scale analysis, data of NO2, SO2, and O3 were acquired from the ozone monitoring instrument (OMI) and data of aerosol optical depth (AOD) were collected from the moderate resolution imaging spectroradiometer (MODIS). For city scale analysis, data of NO2, CO, PM2.5, O3, and SO2 were derived from ground-based air quality observations. Results from satellite observations at the continental scale showed that concentrations of NO2, SO2, and AOD substantially dropped in 2020 during the lockdown period compared to their averages for the baseline period over all continents, with a maximum reduction of ~33% for NO2 in East Asia, ~41% for SO2 in East Asia, and ~37% for AOD in South Asia. In the case of O3, the maximum overall reduction was observed as ~11% in Europe, followed by ~10% in North America, while a slight increase was found in other study regions. These findings align with ground-based air quality observations, which showed that pollutants such as NO2, CO, PM2.5, and SO2 during the 2020 lockdown period decreased significantly except that O3 had varying patterns in different cities. Specifically, a maximum reduction of ~49% in NO2 was found in London, ~43% in CO in Wuhan, ~38% in PM2.5 in Chennai, and ~48% in SO2 in Beijing. In the case of urban O3, a maximum reduction of ~43% was found in Wuhan, but a significant increase of ~47% was observed in Chennai. It is obvious that restricted human activities during the lockdown have reduced the anthropogenic emissions and subsequently improved air quality, especially across the metropolitan cities.

Zhang, Zhijie, et al. "Unprecedented Temporary Reduction in Global Air Pollution Associated with COVID-19 Forced Confinement: A Continental and City Scale Analysis." Remote Sensing 12.15 (2020): 2420.

Significant impacts of COVID-19 lockdown on urban air pollution in Kolkata (India) and amelioration of environmental health

The fatal novel coronavirus (COVID-19) pandemic disease smashes the normal tempo of global socio-economic and cultural livelihood. Most of the countries impose a lockdown system with social distancing measures to arrest the rapid transmission of this virus into the human body. The objective of this study is to examine the status of air quality during and pre-COVID-19 lockdown and to recommend some long-term sustainable environmental management plan. The pollution data like PM10, PM2.5, O3, SO2, NO2 and CO have been obtained from State Pollution Control Board under Govt. of West Bengal. Similarly, various land surface temperature (LST) maps have been prepared using LANDSAT-8 OLI and LANDSAT-7 ETM + images of USGS. The maps of NO2 and aerosol concentration over Indian subcontinent have been taken from ESA

and NASA. The digital thematic maps and diagrams have been depicted by Grapher 13 and Arc GIS 10.3 platforms. The result shows that the pollutants like CO, NO2 and SO2 are significantly decreased, while the average level of O3 has been slightly increased in 2020 during the lockdown due to close-down of all industrial and transport activities. Meanwhile, around 17.5% was the mean reduction of PM10 and PM2.5 during lockdown compared with previous years owing to complete stop of vehicles movement, burning of biomass and dust particles from the construction works. This study recommends some air pollution-tolerant plant species (in urban vacant spaces and roof tops) for long-term cohabitation among environment, society and development.

Bera, Biswajit, et al. "Significant impacts of COVID-19 lockdown on urban air pollution in Kolkata (India) and amelioration of environmental health." Environment, Development and Sustainability (2020): 1-28.

The short-term impacts of COVID-19 lockdown on urban air pollution in China

To prevent the escalation of COVID-19 transmission, China locked down one-third of its cities, which strictly curtailed personal mobility and economic activities. Using comprehensive daily air quality data in China, we evaluated the impacts of these measures in terms of the Air Quality Index (AQI) and the concentrations of particulate matter with a diameter of less than 2.5 μm (PM2.5). To infer their causal relationships, we employed difference-in-differences models that compare cities with and without lockdown policies. We found that city lockdowns led to a sizeable improvement in air quality. Within weeks, the AQI in the locked-down cities was brought down by 19.84 points (PM2.5 down by 14.07 μg m-3) relative to the control group. In addition, air quality in cities without formal lockdowns also improved because of the enforcement of other types of counter-virus measures. The AQI in those cities was brought down by 6.34 points (PM2.5 down by 7.05 μg m-3) relative to the previous year. The lockdown effects are larger in colder, richer and more industrialized cities. Despite these improvements, PM2.5 concentrations during the lockdown periods remained four times higher than the World Health Organization recommendations, suggesting much further effort is needed. Existing environmental policies could obtain similar air quality improvements at a much lower economic cost, making city lockdowns an unsustainable option to address environmental issues.

He, Guojun, Yuhang Pan, and Takanao Tanaka. "The short-term impacts of COVID-19 lockdown on urban air pollution in China." Nature Sustainability (2020): 1-7.

The impact of COVID-19 as a necessary evil on air pollution in India during the lockdown

The study objective is to contemplate the effectiveness of COVID-19 on the air pollution of Indian territory from January 2020 to April 2020. We have executed data from European Space Agency (ESA) and CPCB online portal for air quality data dissemination. The Sentinel – 5 P satellite images elucidate that the Air quality of Indian territory has been improved significantly during COVID-19. Mumbai and Delhi are one of the most populated cities. These two cities have observed a substantial decrease in Nitrogen Dioxide (40–50%) compared to the same period last year. It suggests that the emergence of COVID-19 has been proved to a necessary evil as being advantageous for mitigating air pollution on Indian territory during the lock-down. The study found a significant decline in Nitrogen Dioxide in reputed states of India, i.e., Delhi and Mumbai. Moreover, a faded track of Nitrogen Dioxide can be seen at the Maritime route in the Indian Ocean. An upsurge in the environmental quality of India will also be beneficial for its neighbor countries, i.e., China, Pakistan, Iran, and Afghanistan.

Sarfraz, Muddassar, Khurram Shehzad, and Syed Ghulam Meran Shah. "The impact of COVID-19 as a necessary evil on air pollution in India during the lockdown." Environmental Pollution (2020): 115080.

COVID-19 Pandemic and City-Level Nitrogen Dioxide (NO 2) Reduction for Urban Centres of India

Air pollution poses a grave health risk and is a matter of concern for researchers around the globe. Toxic pollutants like nitrogen dioxide (NO2) is a result of industrial and transport sector emissions and need to be analysed at the current scenario. After the world realised the effect of COVID-19 pandemic, countries around the globe proposed complete lockdown to contain the spread. The present research focuses on analysing the gaseous pollution scenarios, before and during lockdown through satellite (Sentinel-5P data sets) and ground-based measurements (Central Pollution Control Board's Air Quality Index, AQI) for 8 five-million plus cities in India (Delhi, Ahmedabad, Kolkata, Mumbai, Hyderabad, Chennai, Bengaluru and Pune). The long-term exposure to NO2 was also linked to pandemic-related mortality cases across the country. An average of 46% reduction in average NO2 values and 27% improvement in AQI was observed in the eight cities during the first lockdown phase with respect to pre-lockdown phase. Also, 53% of Corona positive cases and 61% of fatality cases were observed in the eight major cities of the country alone, coinciding with locations having high long-term NO2 exposure.

Siddiqui, Asfa, et al. "COVID-19 Pandemic and City-Level Nitrogen Dioxide (NO 2) Reduction for Urban Centres of India." Journal of the Indian Society of Remote Sensing (2020): 1-8.

Gauging the air quality of New York: a non-linear Nexus between COVID-19 and nitrogen dioxide emission

The primary objective of the study is to analyse the relationship between COVID-19 and nitrogen dioxide in New York City during the global pandemic. Notably, the study has investigated the direct influence of lockdown circumstances (due to COVID-19) and plunge in the population of New York on its environmental contamination. The study utilized the Non-Linear Autoregressive Distributed Lag (NARDL) model to ascertain the asymmetric impact of COVID-19 on the environmental quality of the USA. The results reveal that lockdown has played a significant role in the environmental quality of the USA. Notably, an escalation in the registered cases of COVID-19 has a meaningful and indirect relationship with environmental pollution in the UAS. Besides, as the lockdown state goes normal, it results in an explosion in the environmental pollution in the USA. Also, deaths due to COVID-19 substantively improve the environmental quality in the short-term period as well as in the long-term period.

Sarfraz, Muddassar, Khurram Shehzad, and Awais Farid. "Gauging the air quality of New York: a non-linear Nexus between COVID-19 and nitrogen dioxide emission." Air Quality, Atmosphere & Health (2020): 1-11.

Decrease in Ambient Fine Particulate Matter during COVID-19 Crisis and Corresponding Health Benefits in Seoul, Korea

Both domestic emissions and transported pollutants from neighboring countries affect the ambient fine particulate matter (PM2.5) concentration of Seoul, Korea. Diverse measures to control the coronavirus disease 2019 (COVID-19), such as social distancing and increased telecommuting in Korea and the stringent lockdown measures of China, may reduce domestic emissions and levels of transported pollutants, respectively. In addition, wearing a particulate-filtering respirator may have decreased the absolute PM2.5 exposure level for individuals. Therefore, this study estimated the acute health benefits of PM2.5 reduction and changes in public behavior during the COVID-19 crisis in Seoul, Korea. To calculate the mortality burden attributable to PM2.5, we obtained residents' registration data, mortality data, and air pollution monitoring data for Seoul from publicly available databases. Relative risks were derived from previous time-series studies. We used the attributable fraction to estimate the number of excessive deaths attributable to acute PM2.5 exposure during January to April, yearly, from 2016 to 2020, and the number of mortalities avoided from PM2.5 reduction and respirator use observed in 2020. The average PM2.5 concentration from January to April in 2020 (25.6 μg/m3) was the lowest in the last 5 years. At least -4.1 μ

g/m3 (95% CI: -7.2, -0.9) change in ambient PM2.5 in Seoul was observed in 2020 compared to the previous 4 years. Overall, 37.6 (95% CI: 32.6, 42.5) non-accidental; 7.0 (95% CI: 5.7, 8.4) cardiovascular; and 4.7 (95% CI: 3.4, 6.1) respiratory mortalities were avoided due to PM2.5 reduction in 2020. By considering the effects of particulate respirator, decreases of 102.5 (95% CI: 89.0, 115.9) non-accidental; 19.1 (95% CI: 15.6, 22.9) cardiovascular; and 12.9 (95% CI: 9.2, 16.5) respiratory mortalities were estimated. We estimated that 37 lives were saved due to the PM2.5 reduction related to COVID-19 in Seoul, Korea. The health benefit may be greater due to the popular use of particulate-filtering respirators during the COVID-19 crisis. Future studies with daily mortality data are needed to verify our study estimates.

Han, Changwoo, and Yun-Chul Hong. "Decrease in Ambient Fine Particulate Matter during COVID-19 Crisis and Corresponding Health Benefits in Seoul, Korea." International Journal of Environmental Research and Public Health 17.15 (2020): 5279.

Impact of COVID-19 lockdown on air quality in Chandigarh, India: Understanding the emission sources during controlled anthropogenic activities

The variation in ambient air quality during COVID-19 lockdown was studied in Chandigarh, located in the Indo-Gangetic plain of India. Total 14 air pollutants, including particulate matter (PM10, PM2.5), trace gases (NO2, NO, NOx, SO2, O3, NH3, CO) and VOC's (benzene, toluene, o-xylene, m,p-xylene, ethylbenzene) were examined along with meteorological parameters. The study duration was divided into four parts, i.e., a) 21 days of before lockdown b) 21 days of the first phase of lockdown c) 19 days of the second phase of lockdown d) 14 days of the third phase of lockdown. The results showed significant reductions during the first and second phases for all pollutants. However, concentrations increased during the third phase. The concentrations of SO2, O3, and m,p-xylene kept on increasing throughout the study period, except for benzene, which continuously decreased. The percentage decrease in the concentrations during consecutive periods of lockdown were 28.8 %, 23.4 % and 1.1 % for PM2.5 and 36.8 %, 22.8 % and 2.4 % for PM10 respectively. The Principal Component Analysis (PCA) and characteristic ratios identified vehicular pollution as a primary source during different phases of lockdown. During the lockdown, residential sources showed a significant adverse impact on the air quality of the city. Regional atmospheric transfer of pollutants from coal-burning and stubble burning were identified as secondary sources of air pollution. The findings of the study offer the potential to plan air pollution reduction strategies in the extreme pollution episodes such as during crop residue burning period over Indo-Gangetic plain.

Mor, Suman, et al. "Impact of COVID-19 lockdown on air quality in Chandigarh, India: Understanding the emission sources during controlled anthropogenic activities." Chemosphere (2020): 127978.

Air pollution improvement and mortality rate during COVID-19 pandemic in India: global intersectional study

This research was carried out using the open-source database system along with the continuous air quality monitoring station results from global data sets during the COVID-19 pandemic lockdown in India and the global. Our purpose of this research is to study the improvement of air quality and human mortality rates in countries worldwide during the COVID-19 pandemic lockdown. Worldwide air quality data were collected from > 12,000 continuous air quality monitoring stations on six continents covering 1000 major cities from over 100 countries. Here, we discussed the implementation of the open-source data set of basic air pollutants such as PM 2.5, NO2, temperature, relative humidity, and Air Quality Index variation during the pre-lockdown and lockdown pandemic COVID-19 in India and described the global aspect. An average concentration of PM 2.5 (145.51 µg/m3), NO2 (21.64 µg/m3), and AQI index (55.58) continuously decreased. The variation of PM 2.5, NO2, normally shows more than 25 µg/m3 every year, but during the COVID-19 lockdown period (April 2020) continuously decreased below 20 µg/m3. Similarly, the AQI index

and meteorological factors such as temperature, relative humidity, and wind speed variation decreased significantly in the many countries in the world. In Asian countries, air quality improved during the national lockdown especially in the most polluted cities globally such as Beijing, Delhi, and Nanjing and also in developed cities like Madrid, New York, Paris, Seoul, Sydney, Tokyo. Furthermore, the reduction of particulate matter was in about 46%, and other gaseous pollutants during the lockdown period were observed in a 54% reduction. We are witnessing pollution reductions which add significantly to improvements in air quality. This is due to the massive decrease in the use of fossil fuel, which in turn reduces production and traffic in general. People nowadays are now willing to see a comparatively healthier world with bleached skies and natural ecosystems. This research finding demonstrates potential safety benefits associated with improving air quality and mortality rates during the COVID-19 pandemic, resulting in decreases in mortality rates in India and around the world.

Karuppasamy, Manikanda Bharath, et al. "Air pollution improvement and mortality rate during COVID-19 pandemic in India: global intersectional study." Air Quality, Atmosphere & Health (2020): 1-10.

The Effects of Air Pollution on COVID-19 Related Mortality in Northern Italy

Long-term exposure to ambient air pollutant concentrations is known to cause chronic lung inflammation, a condition that may promote increased severity of COVID-19 syndrome caused by the novel coronavirus (SARS-CoV-2). In this paper, we empirically investigate the ecologic association between long-term concentrations of area-level fine particulate matter (PM2.5) and excess deaths in the first quarter of 2020 in municipalities of Northern Italy. The study accounts for potentially spatial confounding factors related to urbanization that may have influenced the spreading of SARS-CoV-2 and related COVID-19 mortality. Our epidemiological analysis uses geographical information (e.g., municipalities) and negative binomial regression to assess whether both ambient PM2.5 concentration and excess mortality have a similar spatial distribution. Our analysis suggests a positive association of ambient PM2.5 concentration on excess mortality in Northern Italy related to the COVID-19 epidemic. Our estimates suggest that a one-unit increase in PM2.5 concentration (µg/m3) is associated with a 9% (95% confidence interval: 6–12%) increase in COVID-19 related mortality.

Coker, Eric S., et al. "The Effects of Air Pollution on COVID-19 Related Mortality in Northern Italy." Environmental and Resource Economics (2020): 1-24.

Air quality variations in Northern South America during the COVID-19 lockdown

Lockdown measures led to air pollution decrease in several countries around the world such as China and India, whereas other regions experimented an increase in pollutant concentrations. Northern South America (NSA) was one of those areas where pollution changed during lockdown due to high fire activity. This study aims to analyze, for the first time in NSA, the behavior of selected criteria air pollutants during the implementation of the SARS-CoV-2 lockdown in two high populated cities of the region: Bogotá and Medellín in Colombia. A set of tools including surface measurements, as well as satellite and modeled data were used. 24-hour average concentrations of PM10, PM2.5, and NO2 were collected from air quality stations for the lockdown period ranging from February 21 to June 30, 2020. The Copernicus Atmosphere Monitoring Service (CAMS) was used to analyze the fire flux OC as a biomass burning (BB) indicator, and tropospheric NO2 concentrations were retrieved from TROPOMI. The HYSPLIT model was used to analyze back trajectories and fire data were obtained from MODIS sensor measurements. Our analysis shows short-term background NO2, PM10, and PM2.5 concentration reductions of 60%, 44%, and 40%, respectively, for the strict lockdown; and 62%, 58%, and 69% for the relaxed lockdown. Corresponding long-term reductions were of 50%, 32%, and 9% for the strict lockdown; and 37%, 29%, and 19% for the relaxed lockdown. Regional BB increased PM2.5 concentrations by 20 µg/m3 during the strict lockdown, and the Saharan dust event increased PM10 concentrations up to 168 µg/m3 in Bogotá, and 104 µg/m3 in

Medellín, bringing an additional risk of morbidity and mortality for population. Regional BB has several causes that need to be properly managed to benefit local air quality improvement plans. Future cleaner transport policies equivalent to reduced lockdown mobility could bring pollution close to WHO guidelines.

Mendez-Espinosa, J. F., et al. "Air quality variations in Northern South America during the COVID-19 lockdown." Science of The Total Environment (2020): 141621.

Implications for air quality management of changes in air quality during lockdown in Auckland (New Zealand) in response to the 2020 SARS-CoV-2 epidemic

The current changes in vehicle movement due to 'lockdown' conditions (imposed in cities worldwide in response to the COVID-19 epidemic) provide opportunities to quantify the local impact of 'controlled interventions' on air quality and establish baseline pollution concentrations in cities. Here, we present a case study from Auckland, New Zealand, an isolated Southern Hemisphere city, which is largely unaffected by long-range pollution transport or industrial sources of air pollution. In this city, traffic flows reduced by 60–80% as a result of a government-led initiative to contain the virus by limiting all transport to only essential services. In this paper, ambient pollutant concentrations of NO2, O3, BC, PM2.5, and PM10 are compared between the lockdown period and comparable periods in the historical air pollution record, while taking into account changes in the local meteorology. We show that this 'natural experiment' in source emission reductions had significant but non-linear impacts on air quality. While emission inventories and receptor modelling approaches confirm the dominance of traffic sources for NOx (86%), and BC (72%) across the city, observations suggest a consequent reduction in NO2 of only 34–57% and a reduction in BC of 55–75%. The observed reductions in PM2.5 (still likely to be dominated by traffic emissions), and PM10 (dominated by sea salt, traffic emissions to a lesser extent, and affected by seasonality) were found to be significantly less (8–17% for PM2.5 and 7–20% for PM10). The impact of this unplanned controlled intervention shows the importance of establishing accurate, local-scale emission inventories, and the potential of the local atmospheric chemistry and meteorology in limiting their accuracy.

Patel, Hamesh, et al. "Implications for air quality management of changes in air quality during lockdown in Auckland (New Zealand) in response to the 2020 SARS-CoV-2 epidemic." Science of The Total Environment (2020): 141129.

Diurnal and temporal changes in air pollution during COVID-19 strict lockdown over different regions of India

Lockdown measures to contain COVID-19 pandemic has resulted in a considerable change in air pollution worldwide. We estimate the temporal and diurnal changes of the six criteria air pollutants, including particulate matter (PM2.5 and PM10) and gaseous pollutants (NO2, O3, CO, and SO2) during lockdown (25th March – 3rd May 2020) across regions of India using the observations from 134 real-time monitoring sites of Central Pollution Control Board (CPCB). Significant reduction in PM2.5, PM10, NO2, and CO has been found in all the regions during the lockdown. SO2 showed mixed behavior, with a slight increase at some sites but a comparatively significant decrease at other locations. O3 also showed a mixed variation with a mild increase in IGP and a decrease in the South. The absolute decrease in PM2.5, PM10, and NO2 was observed during peak morning traffic hours (08–10 Hrs) and late evening (20–24 Hrs), but the percentage reduction is almost constant throughout the day. A significant decrease in day-time O3 has been found over Indo Gangetic plain (IGP) and central India, whereas night-time O3 has increased over IGP due to less O3 loss. The most significant reduction (~40–60%) was found in PM2.5 and PM10. The highest decrease in PM was found for the north-west and IGP followed by South and central regions. A considerable reduction (~30–70%) in NO2 was found except for a few sites in the central region. A similar

pattern was observed for CO having a ~20–40% reduction. The reduction observed for PM2.5, PM10, NO2, and enhancement in O3 was proportional to the population density. Delhi's air quality has improved with a significant reduction in primary pollutants, however, an increase in O3 was observed. The changes reported during the lockdown are combined effect of changes in the emissions, meteorology, and atmospheric chemistry that requires detailed investigations.

Singh, Vikas, et al. "Diurnal and temporal changes in air pollution during COVID-19 strict lockdown over different regions of India." Environmental Pollution (2020): 115368.

Changes in Air Quality during the COVID-19 Lockdown in Singapore and Associations with Human Mobility Trends

On the 7th of April, the Singaporean government enforced strict lockdown measures with the aim of reducing the transmission chain of the coronavirus disease 2019. This had a significant impact on the movement of people within the country. Our study aims to quantify the impact that these measures had on outdoor air pollution levels. We obtained air quality and weather data from April 2016 to May 2020, satellite data for 2019 and 2020 and mobility data for 2020 from Apple, Google, and the Singaporean Housing & Development Board. We determined that outdoor air pollution during the lockdown significantly decreased when compared with the same period in the previous four years even if we included corrections for long time trends in the analysis. The concentrations of the following pollutants PM10, PM2.5, NO2, CO, and SO2 decreased by 23, 29, 54, 6, and 52%, respectively, whilst that of O3 increased by 18%. The Pollutant Standard Index decreased by 19%. The trends of PM2.5 and NO2 were significantly correlated with mobility data. The NO2 and SO2 tropospheric concentrations and the total aerosol optical depth at 550 nm obtained from satellite data during the lockdown in 2020 were also lower than during the same period in 2019. Our results can be used to evaluate possible mitigation strategies for outdoor air quality in a longer term beyond this lockdown.

Li, Jiayu, and Federico Tartarini. "Changes in Air Quality during the COVID-19 Lockdown in Singapore and Associations with Human Mobility Trends." Aerosol and Air Quality Research 20 (2020): 1748-1758.

Evidence-Based Considerations Exploring Relations between SARS-CoV-2 Pandemic and Air Pollution: Involvement of PM2.5-Mediated Up-Regulation of the Viral Receptor ACE-2.

The COVID-19/SARS-CoV-2 pandemic struck health, social and economic systems worldwide, and represents an open challenge for scientists —coping with the high inter-individual variability of COVID-19, and for policy makers —coping with the responsibility to understand environmental factors affecting its severity across different geographical areas. Air pollution has been warned of as a modifiable factor contributing to differential SARS-CoV-2 spread but the biological mechanisms underlying the phenomenon are still unknown. Air quality and COVID-19 epidemiological data from 110 Italian provinces were studied by correlation analysis, to evaluate the association between particulate matter (PM)2.5 concentrations and incidence, mortality rate and case fatality risk of COVID-19 in the period 20 February–31 March 2020. Bioinformatic analysis of the DNA sequence encoding the SARS-CoV-2 cell receptor angiotensin-converting enzyme 2 (ACE-2) was performed to identify consensus motifs for transcription factors mediating cellular response to pollutant insult. Positive correlations between PM2.5 levels and the incidence ($r = 0.67$, $p < 0.0001$), the mortality rate ($r = 0.65$, $p < 0.0001$) and the case fatality rate ($r = 0.7$, $p < 0.0001$) of COVID-19 were found. The bioinformatic analysis of the ACE-2 gene identified nine putative consensus motifs for the aryl hydrocarbon receptor (AHR). Our results confirm the supposed link between air pollution and the rate and outcome of SARS-CoV-2 infection and support the hypothesis that pollution-induced over-expression of ACE-2 on human airways may favor SARS-CoV-2 infectivity.

Borro, Marina, et al. "Evidence-Based Considerations Exploring Relations between SARS-CoV-2 Pandemic and Air Pollution: Involvement of PM2. 5-Mediated Up-Regulation of the Viral Receptor ACE-2." International Journal of Environmental Research and Public Health 17.15 (2020): 5573.

NO 2levels after the COVID-19 lockdown in Ecuador: A trade-off between environment and human health

The negative effects on human health, along with the fatalities caused by the new coronavirus, have led governments worldwide to take strict measures. However, a reduction in air pollution has been found in many regions on a global scale. This study is focused on how the COVID-19 pandemic is impacting on the air quality in Ecuador, one of the most alarming cases of COVID-19 contagion in Latin America, occupying the first place as regards deaths per capita. The spatio-temporal variations in NO2 concentrations in 12 highly populated cities were evaluated by comparing the NO2 tropospheric concentrations before (2019) and after (2020) the COVID-19 lockdown. The atmospheric data was collected from the TROPOMI on the Sentinel-5P satellite of the European Space Agency. A reduction in NO2 concentrations (-13%) was observed as a consequence of the COVID-19 lockdown in Ecuador. However, this reduction occurred to the greatest extent in the cases of Guayaquil (-23.4%) and Quito (-22.4%), the two most highly populated cities. Linking NO2 levels to confirmed cases/deaths of COVID-19, a strong correlation between air NO2 concentrations and the cases/mortality caused by coronavirus ($r = 0.91$; $p<0.001$) was observed. This work highlights the crucial role played by air quality as regards human health.

Pacheco, Henry, et al. "NO2 levels after the COVID-19 lockdown in Ecuador: A trade-off between environment and human health." Urban Climate 34 (2020): 100674.

Impact of climate and ambient air pollution on the epidemic growth during COVID-19 outbreak in Japan.

Coronavirus disease 2019 (COVID-19) rapidly spread worldwide in the first quarter of 2020 and resulted in a global crisis. Investigation of the potential association of the spread of the COVID-19 infection with climate or ambient air pollution could lead to the development of preventive strategies for disease control. To examine this association, we conducted a longitudinal cohort study of 28 geographical areas of Japan with documented outbreaks of COVID-19. We analyzed data obtained from March 13 to April 6, 2020, before the Japanese government declared a state of emergency. The results revealed that the epidemic growth of COVID-19 was significantly associated with increase in daily temperature or sunshine hours. This suggests that an increase in person-to-person contact due to increased outing activities on a warm and/or sunny day might promote the transmission of COVID-19. Our results also suggested that short-term exposure to suspended particles might influence respiratory infections caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Further research by well-designed or well-controlled study models is required to ascertain this effect. Our findings suggest that weather has an indirect role in the transmission of COVID-19 and that daily adequate preventive behavior decreases the transmission.

Azuma, Kenichi, et al. "Impact of climate and ambient air pollution on the epidemic growth during COVID-19 outbreak in Japan." Environmental Research (2020): 110042.

Impact Assessment of COVID-19 on Variations of SO2, NO2, CO and AOD over East China

The COVID-19 (Coronavirus Disease 2019) broke out in the late of 2019. On January 23 in Wuhan, and later in all other cities of the country, there were taken measures to control the spread of the virus through quarantine measures. This article focused on East China and attempted to assess comprehensively the environmental impact of the COVID-19 outbreak. This study analyzed satellite observational data of sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO) and aerosol optical depth (AOD) in the period

before the outbreak of the epidemic and during the implementation of preventive measures and control of COVID-19, as well as compared it with the data obtained in the same period of 2019. The results of the analysis showed that the COVID-19 lockdown improved air quality in the short term, but as soon as coal consumption at power plants and refineries returned to normal levels due to the resumption of their work, pollution levels returned to their previous level. The levels of CO and NO2 showed the most significant decrease (20 and 30%), since they were mainly associated with a decrease in economic growth and transport restrictions that led to a change in energy consumption and a reduction in emissions. This study can complement the scientific community and environmental protection policy makers, not only to assess the impact of outbreak on air quality, but also for its effectiveness as a simple alternative program of action to improve air quality.

Filonchyk, Mikalai, et al. "Impact Assessment of COVID-19 on Variations of SO2, NO2, CO and AOD over East China." Aerosol and Air Quality Research 20.

Potential link between compromised air quality and transmission of the novel corona virus (SARS-CoV-2) in affected areas

The emergence of a novel human corona virus disease (COVID-19) has been declared as a pandemic by the World Health Organization. One of the mechanisms of airborne transmission of the severe acute respiratory syndrome - corona virus (SARS-CoV-2) amid humans is through direct ejection of droplets via sneezing, coughing and vocalizing. Nevertheless, there are ample evidences of the persistence of infectious viruses on inanimate surfaces for several hours to a few days. Through a critical review of the current literature and a preliminary analysis of the link between SARS-CoV-2 transmission and air pollution in the affected regions, we offer a perspective that polluted environment could enhance the transmission rate of such deadly viruses under moderate-to-high humidity conditions. The aqueous atmospheric aerosols offer a conducive surface for adsorption/absorption of organic molecules and viruses onto them, facilitating a pathway for higher rate of transmission under favourable environmental conditions. This mechanism partially explains the role of polluted air besides the exacerbation of chronic respiratory diseases in the rapid transmission of the virus amongst the public. Hence, it is stressed that more ambitious policies towards a cleaner environment are required globally to nip in the bud what could be the seeds of a fatal outbreak such as COVID-19.

Manoj, M. G., et al. "Potential link between compromised air quality and transmission of the novel corona virus (SARS-CoV-2) in affected areas." Environmental Research (2020): 110001.

Spatiotemporal impacts of COVID-19 on air pollution in California, USA

Various recent studies have shown that societal efforts to mitigate (e.g. “lockdown”) the outbreak of the 2019 coronavirus disease (COVID-19) caused non-negligible impacts on the environment, especially air quality. To examine if interventional policies due to COVID-19 have had a similar impact in the US state of California, this paper investigates the spatiotemporal patterns and changes in air pollution before, during and after the lockdown of the state, comparing the air quality measurements in 2020 with historical averages from 2015 to 2019. Through time series analysis, a sudden drop and uptick of air pollution are found around the dates when shutdown and reopening were ordered, respectively. The spatial patterns of nitrogen dioxide (NO2) tropospheric vertical column density (TVCD) show a decreasing trend over the locations of major powerplants and an increasing trend over residential areas near interactions of national highways. Ground-based observations around California show a 38%, 49%, and 31% drop in the concentration of NO2, carbon monoxide (CO) and particulate matter 2.5 (PM2.5) during the lockdown (March 19–May 7) compared to before (January 26–March 18) in 2020. These are 16%, 25% and 19% sharper than the means of the previous five years in the same periods, respectively. Our study offers

evidence of the environmental impact introduced by COVID-19, and insight into related economic influences.

Liu, Qian, et al. "Spatiotemporal impacts of COVID-19 on air pollution in California, USA." Science of The Total Environment (2020): 141592.

Air Quality Response in China Linked to the 2019 Novel Coronavirus (COVID-19) Lockdown

Efforts to stem the spread of COVID-19 in China hinged on severe restrictions to human movement starting 23 January 2020 in Wuhan and subsequently to other provinces. Here, we quantify the ancillary impacts on air pollution and human health using inverse emissions estimates based on multiple satellite observations. We find that Chinese NOx emissions were reduced by 36% from early January to mid-February, with more than 80% of reductions occurring after their respective lockdown in most provinces. The reduced precursor emissions increased surface ozone by up to 16 ppb over northern China but decreased PM2.5 by up to 23 µg m-3 nationwide. Changes in human exposure are associated with about 2,100 more ozone-related and at least 60,000 fewer PM2.5-related morbidity incidences, primarily from asthma cases, thereby augmenting efforts to reduce hospital admissions and alleviate negative impacts from potential delayed treatments.

Miyazaki, Kazuyuki, et al. "Air quality response in China linked to the 2019 novel Coronavirus (COVID-19) mitigation." (2020).

Understanding the lockdown impact in Delhi due to COVID-19 by using micro level temporal analysis of six criteria pollutants

Coronavirus disease 2019 (COVID-19), has become a severe public health problem globally. Government of India has initially decided for 21 days complete lockdown (which had extended further 33 days more) to stop transmission of the virus. The relationship between the characterized air pollutants over a specific monitoring site in Delhi (Delhi Technological University, Delhi) and prevailing lockdown impact, has been addressed through the study of the concentration of pollutants before lockdown and during the lockdown, and by trend analysis of Air Quality Index. It is noticed that O_3 rather than SO_2, CO, PM10, PM2.5 and NO_2 was dominant in this region during the lockdown period. We have considered daily 24 hourly average data of PM10, PM2.5, NO_2, SO_2, and 8 hourly average data of O_3 and CO at DTU, Delhi, besides Daily Air Quality Index (AQI) data for 09 major polluted cities of India, as collected from Central Pollution Control Board (CPCB) between March 25, 2019 to April 14, 2019 (before lockdown) and from March 25, 2020 to April 14, 2020 (during lockdown). Our results indicate that the average concentration of NO_2, CO, SO_2, PM10 and PM2.5 reduced by 54.36%, 75.63%, 37.16%, 62.30%, 46.75% respectively but the concentration of O_3 increased by 37.49% during the lockdown period over the specific monitoring site in Delhi. The trend analysis over DTU, Delhi monitoring site, shows that the trends of NO_2, SO_2, PM2.5, PM10 and O_3 have been increasing constantly, except CO, before the lockdown period.

Saxena, Harshita, and Vivek Kumar Pandey. "Understanding the lockdown impact in Delhi due to COVID-19 by using micro level temporal analysis of six criteria pollutants." J. Ind. Geophys. Union 24.3 (2020): 72-79.

Lower air pollution during COVID-19 lock-down: improving models and methods estimating ozone impacts on crops

We suggest that the unprecedented and unintended decrease of emissions of air pollutants during the COVID-19 lock-down in 2020 could lead to declining seasonal ozone concentrations and positive impacts on crop yields. An initial assessment of the potential effects of COVID-19 emission reductions was made using a set of six scenarios that variously assumed annual European and global emission reductions of 30% and

50% for the energy, industry, road transport and international shipping sectors, and 80% for the aviation sector. The greatest ozone reductions during the growing season reached up to 12 ppb over crop growing regions in Asia and up to 6 ppb in North America and Europe for the 50% global reduction scenario. In Europe, ozone responses are more sensitive to emission declines in other continents, international shipping and aviation than to emissions changes within Europe. We demonstrate that for wheat the overall magnitude of ozone precursor emission changes could lead to yield improvements between 2% and 8%. The expected magnitude of ozone precursor emission reductions during the Northern Hemisphere growing season in 2020 presents an opportunity to test and improve crop models and experimentally based exposure response relationships of ozone impacts on crops, under real-world conditions.

Dentener, Frank, et al. "Lower air pollution during COVID-19 lock-down: improving models and methods estimating ozone impacts on crops." Philosophical Transactions of the Royal Society A 378.2183 (2020): 20200188.

Changes in Ambient Air Quality and Atmospheric Composition and Reactivity in the South East of the UK as a Result of the COVID-19 Lockdown

The COVID-19 pandemic forced governments around the world to impose restrictions on daily life to prevent the spread of the virus. This resulted in unprecedented reductions in anthropogenic activity, and reduced emissions of certain air pollutants, namely oxides of nitrogen. The UK 'lockdown' was enforced on 23/03/2020, which led to restrictions on movement, social interaction, and 'non-essential' businesses and services. This study employed an ensemble of measurement and modelling techniques to investigate changes in air quality, atmospheric composition and boundary layer reactivity in the South East of the UK post-lockdown. The techniques employed included in-situ gas- and particle-phase monitoring within central and local authority air quality monitoring networks, remote sensing by long path Differential Optical Absorption Spectroscopy and Sentinel-5P's TROPOMI, and detailed 0-D chemical box modelling. Findings showed that de-trended NO2 concentrations decreased by an average of 14-38% when compared to the mean of the same period over the preceding 5-years. We found that de-trended particulate matter concentrations had been influenced by interregional pollution episodes, and de-trended ozone concentrations had increased across most sites, by up to 15%, such that total Ox levels were roughly preserved. 0-D chemical box model simulations showed the observed increases in ozone concentrations during lockdown under the hydrocarbon-limited ozone production regime, where total NOx decreased proportionally greater than total non-methane hydrocarbons, which led to an increase in total hydroxyl, peroxy and organic peroxy radicals. These findings suggest a more complex scenario in terms of changes in air quality owing to the COVID-19 lockdown than originally reported and provide a window into the future to illustrate potential outcomes of policy interventions seeking large-scale NOx emissions reductions without due consideration of other reactive trace species.

Wyche, K. P., et al. "Changes in Ambient Air Quality and Atmospheric Composition and Reactivity in the South East of the UK as a Result of the COVID-19 Lockdown." Science of The Total Environment (2020): 142526.

Four-Month Changes in Air Quality during and after the COVID-19 Lockdown in Six Megacities in China

The pandemic of coronavirus disease 2019 (COVID-19) resulted in a stringent lockdown in China to reduce the infection rate. We adopted a machine learning technique to analyze the air quality impacts of the COVID-19 lockdown from January to April 2020 for six megacities with different lockdown durations. Compared with the scenario without lockdowns, we estimated that the lockdown reduced ambient NO2 concentrations by 36–53% during the most restrictive periods, which involved Level-1 public health emergency response control actions. Several cities lifted the Level-1 control actions during February and March, and the avoided NO2 concentrations subsequently dropped below 10% in late April. Traffic analysis

during the same periods in Beijing and Chengdu confirmed that traffic emission changes were a major factor in the substantial NO2 reduction, but they were also associated with increased O3 concentrations. The lockdown also reduced PM2.5 concentrations, although heavy pollution episodes occurred on certain days due to the enhanced formation of secondary aerosols in association with the increased atmospheric oxidizing capacity. We also observed that the changes in air pollution levels decreased as the lockdown was gradually eased in various cities.

Wang, Yunjie, et al. "Four-month changes in air quality during and after the COVID-19 lockdown in six megacities in China." Environmental Science & Technology Letters (2020).

Temporary reduction in air pollution due to anthropogenic activity switch-off during COVID-19 lockdown in northern parts of India

Due to fast and deadly spread of corona virus (COVID-19), the Government of India implemented lockdown in the entire country from 25 April 2020. So, we studied the differences in the air quality index (AQI) of Delhi (DTU, Okhla and Patparganj), Haryana (Jind, Palwal and Hisar) and Uttar Pradesh (Agra, Kanpur and Greater Noida) from 17 February 2020 to 4 May 2020. The AQI was calculated by combination of individual sub-indices of seven pollutants, namely PM2.5, PM10, NO2, NH3, SO2, CO and O3, collected from the Central Pollution Control Board website. The AQI has improved by up to 30–46.67% after lockdown. The AQI slope values -1.87, -1.70 and -1.35 were reported for Delhi, -1.11, -1.31 and -1.04 were observed for Haryana and -1.48, -1.79 and -1.78 were found for Uttar Pradesh (UP), which may be attributed to limited access of transportation and industrial facilities due to lockdown. The ozone (O3) concentration was high at Delhi because of lesser greenery as compared to UP and Haryana, which provides higher atmospheric temperature favourable for O3 formation. The air mass back trajectory (AMBT) analysis reveals the contribution of air mass from Europe, Africa and Gulf countries as well as local emissions from Indo-Gangetic Plain, Madhya Pradesh and Maharashtra states of India.

Gautam, Alok Sagar, et al. "Temporary reduction in air pollution due to anthropogenic activity switch-off during COVID-19 lockdown in northern parts of India." Environment, Development and Sustainability (2020): 1-24.

Impact of Lockdown on Ambient Air Quality in COVID-19 Affected Hotspot Cities of India: Need to Readdress Air Pollution Mitigation Policies

The present study investigates the effect of lockdown on ambient air quality of 16 Indian cities constituting the major hotspots for COVID-19 cases. The COVID-19 lockdown resulted in cleaner air in India. Significant reduction of nearly 62%, 52% and 69% are observed in PM10, PM2.5 and NO2 levels as compared to preceding years. However, there is no significant effect of lockdown on other gaseous pollutants (SO2 and O3). The lockdown in India was found to be an effective way to restrict the virus spread rate and measure control ambient air pollutant levels.

Garg, Anchal, Arvind Kumar, and N. C. Gupta. "Impact of Lockdown on Ambient Air Quality in COVID-19 Affected Hotspot Cities of India: Need to Readdress Air Pollution Mitigation Policies." Environmental Claims Journal (2020): 1-12.

Quantifying road traffic impact on air quality in urban areas: A Covid19-induced lockdown analysis in Italy

Covid19-induced lockdown measures caused modifications in atmospheric pollutant and greenhouse gas emissions. Urban road traffic was the most impacted, with 48–60% average reduction in Italy. This offered an unprecedented opportunity to assess how a prolonged (~2 months) and remarkable abatement of traffic emissions impacted on urban air quality. Six out of the eight most populated cities in Italy with different climatic conditions were analysed: Milan, Bologna, Florence, Rome, Naples, and Palermo. The

selected scenario (24/02/2020–30/04/2020) was compared to a meteorologically comparable scenario in 2019 (25/02/2019–02/05/2019). NO2, O3, PM2.5 and PM10 observations from 58 air quality and meteorological stations were used, while traffic mobility was derived from municipality-scale big data.

NO2 levels remarkably dropped over all urban areas (from -24.9% in Milan to -59.1% in Naples), to an extent roughly proportional but lower than traffic reduction. Conversely, O3 concentrations remained unchanged or even increased (up to 13.7% in Palermo and 14.7% in Rome), likely because of the reduced O3 titration triggered by lower NO emissions from vehicles, and lower NOx emissions over typical VOCs-limited environments such as urban areas, not compensated by comparable VOCs emissions reductions. PM10 exhibited reductions up to 31.5% (Palermo) and increases up to 7.3% (Naples), while PM2.5 showed reductions of ∼13–17% counterbalanced by increases up to ∼9%. Higher household heating usage (+16 – 19% in March), also driven by colder weather conditions than 2019 (-0.2 to – 0.8 °C) may partly explain primary PM emissions increase, while an increase in agriculture activities may account for the NH3 emissions increase leading to secondary aerosol formation. This study confirmed the complex nature of atmospheric pollution even when a major emission source is clearly isolated and controlled, and the need for consistent decarbonisation efforts across all emission sectors to really improve air quality and public health.

Gualtieri, Giovanni, et al. "Quantifying road traffic impact on air quality in urban areas: a Covid19-induced lockdown analysis in Italy." Environmental Pollution (2020): 115682.

Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes

This paper analyses the impact of the control measures during the COVID-19 lockdown in Europe (15 March–30 April 2020) on 1-h daily maximum nitrogen dioxide (NO2) and maximum daily 8-h running average ozone (MDA8 O3) observations obtained from the European Environment Agency's air quality database (AirBase). Daily maximum NO2 decreased consistently over the whole continent, with relative reductions ranging from 5% to 55% with respect to the same period in 2015–2019 for 80% of the sites considered (10th – 90th percentiles). However, MDA8 O3 concentrations showed a different pattern, decreasing over Iberia and increasing elsewhere. In particular, a large region from northwestern to central Europe experienced increases of 10–22% at urban background stations, reaching typical values of the summer season. The analysis of the expected NO2 and O3 concentrations in the absence of the lockdown, using generalised additive models fed by reanalysis meteorological data, shows that the low NO2 concentrations were mostly attributed to the emission reductions while O3 anomalies were dominated by the meteorology. The relevance of each meteorological variable depends on the location. The positive O3 anomalies in northwestern and central Europe were mostly associated with elevated temperatures, low specific humidity and enhanced solar radiation. This pattern could be an analogue to study the limits of pollution control policies under climate change scenarios. On the other hand, the O3 reduction in Iberia is mostly attributable to the low solar radiation and high specific humidity, although the reduced zonal wind also played a role in the proximity of the Iberian Mediterranean coast.

Ordóñez, Carlos, Jose M. Garrido-Perez, and Ricardo García-Herrera. "Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes." Science of the Total Environment 747 (2020): 141322.

Implications for air quality management of changes in air quality during lockdown in Auckland (New Zealand) in response to the 2020 SARS-CoV-2 epidemic

The current changes in vehicle movement due to ‘lockdown’ conditions (imposed in cities worldwide in response to the COVID-19 epidemic) provide opportunities to quantify the local impact of ‘controlled

interventions' on air quality and establish baseline pollution concentrations in cities. Here, we present a case study from Auckland, New Zealand, an isolated Southern Hemisphere city, which is largely unaffected by long-range pollution transport or industrial sources of air pollution. In this city, traffic flows reduced by 60–80% as a result of a government-led initiative to contain the virus by limiting all transport to only essential services. In this paper, ambient pollutant concentrations of NO2, O3, BC, PM2.5, and PM10 are compared between the lockdown period and comparable periods in the historical air pollution record, while taking into account changes in the local meteorology. We show that this 'natural experiment' in source emission reductions had significant but non-linear impacts on air quality. While emission inventories and receptor modelling approaches confirm the dominance of traffic sources for NOx (86%), and BC (72%) across the city, observations suggest a consequent reduction in NO2 of only 34–57% and a reduction in BC of 55–75%. The observed reductions in PM2.5 (still likely to be dominated by traffic emissions), and PM10 (dominated by sea salt, traffic emissions to a lesser extent, and affected by seasonality) were found to be significantly less (8–17% for PM2.5 and 7–20% for PM10). The impact of this unplanned controlled intervention shows the importance of establishing accurate, local-scale emission inventories, and the potential of the local atmospheric chemistry and meteorology in limiting their accuracy.

Patel, Hamesh, et al. "Implications for air quality management of changes in air quality during lockdown in Auckland (New Zealand) in response to the 2020 SARS-CoV-2 epidemic." Science of the Total Environment 746 (2020): 141129.

90 Days of COVID-19 Social Distancing and Its Impacts on Air Quality and Health in Sao Paulo, Brazil

The COVID-19 pandemic has imposed a unique situation for humanity, reaching up to 5623 deaths in Sao Paulo city during the analyzed period of this study. Due to the measures for social distancing, an improvement of air quality was observed worldwide. In view of this scenario, we investigated the air quality improvement related to PM10, PM2.5, and NO2 concentrations during 90 days of quarantine compared to an equivalent period in 2019. We found a significant drop in air pollution of 45% of PM10, 46% of PM2.5, and 58% of NO2, and using a relative-risk function, we estimated that this significant air quality improvement avoided, respectively, 78, 337, and 387 premature deaths, respectively, and prevented approximately US $720 million on health costs. Moreover, we estimated that 5623 deaths by COVID-19 represent an economic health loss of US $10.5 billion. Both health and economic gains associated with air pollution reductions give a positive perspective of the efforts towards keeping air pollution reduced even after the pandemic, highlighting the importance of improving the strategies of air pollution mitigation actions, as well as the crucial role of adopting efficient measures to protect human health both during and after the COVID-19 global health crisis.

Debone, Daniela, Mariana V. da Costa, and Simone GEK Miraglia. "90 days of COVID-19 social distancing and its impacts on air quality and health in Sao Paulo, Brazil." Sustainability 12.18 (2020): 7440.

Effect of Lockdown Measures on Atmospheric Nitrogen Dioxide during SARS-CoV-2 in Spain

The disease caused by SARS-CoV-2 has affected many countries and regions. In order to contain the spread of infection, many countries have adopted lockdown measures. As a result, SARS-CoV-2 has negatively influenced economies on a global scale and has caused a significant impact on the environment. In this study, changes in the concentration of the pollutant Nitrogen Dioxide (NO2) within the lockdown period were examined as well as how these changes relate to the Spanish population. NO2 is one of the reactive nitrogen oxides gases resulting from both anthropogenic and natural processes. One major source in urban areas is the combustion of fossil fuels from vehicles and industrial plants, both of which significantly contribute to air pollution. The long-term exposure to NO2 can also cause severe health problems. Remote sensing is a useful tool to analyze spatial variability of air quality. For this purpose, Sentinel-5P images

registered from January to April of 2019 and 2020 were used to analyze spatial distribution of NO2 and its evolution under the lockdown measures in Spain. The results indicate a significant correlation between the population's activity level and the reduction of NO2 values.

Mesas-Carrascosa, Francisco-Javier, et al. "Effect of Lockdown Measures on Atmospheric Nitrogen Dioxide during SARS-CoV-2 in Spain." Remote Sensing 12.14 (2020): 2210.

NOx Emissions Reduction and Rebound in China Due to the COVID-19 Crisis

During the COVID-19 lockdown (24 January–20 March) in China low air pollution levels were reported in the media as a consequence of reduced economic and social activities. Quantification of the pollution reduction is not straightforward due to effects of transport, meteorology, and chemistry. We have analyzed the NOx emission reductions calculated with an inverse algorithm applied to daily NO2 observations from TROPOMI onboard the Copernicus Sentinel-5P satellite. This method allows the quantification of emission reductions per city and the analysis of emissions of maritime transport and of the energy sector separately. The reductions we found are 20–50% for cities, about 40% for power plants, and 15–40% for maritime transport depending on the region. The reduction in both emissions and concentrations shows a similar timeline consisting of a sharp reduction (34–50%) around the Spring festival and a slow recovery from mid-February to mid-March.

Ding, Jieying, et al. "NOx emissions reduction and rebound in China due to the COVID-19 crisis." Geophysical Research Letters (2020): e2020GL089912.

Asymmetric link between environmental pollution and COVID-19 in the top ten affected states of US: A novel estimations from quantile-on-quantile approach

This study draws the link between COVID-19 and air pollution (ground ozone O3) from February 29, 2020 to July 10, 2020 in the top 10 affected States of the US. Utilizing quantile-on-quantile (QQ) estimation technique, we examine in what manner the quantiles of COVID-19 affect the quantiles of air pollution and vice versa. The primary findings confirm overall dependence between COVID-19 and air pollution. Empirical results exhibit a strong negative effect of COVID-19 on air pollution in New York, Texas, Illinois, Massachusetts, and Pennsylvania; especially at medium to higher quantiles, while New Jersey, Illinois, Arizona, and Georgia show strong negative effect mainly at lower quantiles. Contrarily, COVID-19 positively affects air pollution in Pennsylvania at extreme lower quantiles. On the other side, air pollution predominantly caused to increase in the intensity of COVID-19 cases across all states except lower quantiles of Massachusetts, and extreme higher quantiles of Arizona and New Jersey, where this effect becomes less pronounced or negative. Concludingly, a rare positive fallout of COVID-19 is reducing environmental pressure, while higher environmental pollution causes to increase the vulnerability of COVID-19 cases. These findings imply that air pollution is at the heart of chronic diseases, therefore the state government should consider these asymmetric channels and introduce appropriate policy measures to reset and control atmospheric emissions.

Razzaq, Asif, et al. "Asymmetric link between environmental pollution and COVID-19 in the top ten affected states of US: A novel estimations from quantile-on-quantile approach." Environmental Research (2020): 110189.

Impacts of Modifiable Factors on Ambient Air Pollution: A Case Study of COVID-19 Shutdowns

COVID-19-related closures offered a novel opportunity to observe and quantify the impact of activity levels of modifiable factors on ambient air pollution in real time. We use data from a network of low-cost Real-time Affordable Multi-Pollutant (RAMP) sensor packages deployed throughout Pittsburgh, Pennsylvania, along with data from Environmental Protection Agency regulatory monitors. The RAMP locations were

divided into four site groups based on land use. Concentrations of PM2.5, CO, and NO2 following the COVID-related closures at each site group were compared to measurements from "business-as-usual" periods. Overall, PM2.5 concentrations decreased across the domain by ~3 µg/m3. The morning rush-hour-induced CO and NO2 concentrations at the high-traffic sites were both reduced by ~50%, which is consistent with observed reductions in commuter traffic (~50%). The morning rush-hour PM2.5 enhancement from traffic emissions was reduced nearly 100%, from 1.4 to ~0 µg/m3 across all site groups. There was no significant change in the industry-related intraday variability of CO and PM2.5 at the industrial sites following the COVID-related closures. If PM2.5 National Ambient Air Quality Standards (NAAQS) are tightened, this natural experiment sheds light on the extent to which reductions in traffic-related emissions can aid in meeting more stringent regulations.

Tanzer-Gruener, Rebecca, et al. "Impacts of modifiable factors on ambient air pollution: A case study of COVID-19 shutdowns." Environmental Science & Technology Letters 7.8 (2020): 554-559.

Substantial nitrogen oxides emission reduction from China due to COVID-19 and its impact on surface ozone and aerosol pollution

A top-down approach was employed to estimate the influence of lockdown measures implemented during the COVID-19 pandemic on NOx emissions and subsequent influence on surface PM2.5 and ozone in China. The nation-wide NOx emission reduction of 53.4% due to the lockdown in 2020 quarter one in China may represent the current upper limit of China's NOx emission control. During the Chinese New Year Holiday (P2), NOx emission intensity in China declined by 44.7% compared to the preceding 3 weeks (P1). NOx emission intensity increased by 20.3% during the 4 weeks after P2 (P3), despite the unchanged NO2 column. It recovered to 2019 level at the end of March (P4). The East China (22°N - 42°N, 102°E - 122°E) received greater influence from COVID-19. Overall NOx emission from East China for 2020 first quarter is 40.5% lower than 2019, and in P4 it is still 22.9% below the same period in 2019. The 40.5% decrease of NOx emission in 2020 first quarter in East China lead to 36.5% increase of surface O3 and 12.5% decrease of surface PM2.5. The elevated O3 promotes the secondary aerosol formation through heterogeneous pathways. We recommend that the complicated interaction between PM2.5 and O3 should be considered in the emission control strategy making process in the future.

Zhang, Qianqian, et al. "Substantial nitrogen oxides emission reduction from China due to COVID-19 and its impact on surface ozone and particle pollution." Science of The Total Environment (2020): 142238.

Changes in outdoor air pollution due to COVID-19 lockdowns differ by pollutant: evidence from Scotland

Objectives To examine the impact of COVID-19 lockdown restrictions in March/April 2020 on concentrations of nitrogen dioxide (NO2) and ambient fine particulate matter (PM2.5) air pollution measured at roadside monitors across Scotland by comparing data with previous years.

Methods Publicly available data of PM2.5 concentrations from reference monitoring systems at sites across Scotland were extracted for the 31-day period immediately following the imposition of lockdown rules on 23 March 2020. Similar data for 2017, 2018 and 2019 were gathered for comparison. Mean period values were calculated from the hourly data and logged values compared using pairwise t-tests. Weather effects were corrected using meteorological normalisation.

Results NO2 concentrations were significantly lower in the 2020 lockdown period than in the previous 3 years ($p<0.001$). Mean outdoor PM2.5 concentrations in 2020 were much lower than during the same period in 2019 ($p<0.001$). However, despite UK motor vehicle journeys reducing by 65%, concentrations in

2020 were within 1 μg/m3 of those measured in 2017 (p=0.66) and 2018 (p<0.001), suggesting that traffic-related emissions may not explain variability of PM2.5 in outdoor air in Scotland.

Conclusions The impact of reductions in motor vehicle journeys during COVID-19 lockdown restrictions may not have reduced ambient PM2.5 concentrations in some countries. There is also a need for work to better understand how movement restrictions may have impacted personal exposure to air pollutants generated within indoor environments.

Dobson, Ruaraidh, and Sean Semple. "Changes in outdoor air pollution due to COVID-19 lockdowns differ by pollutant: evidence from Scotland." Occupational and Environmental Medicine (2020).

Impacts of nationwide lockdown due to COVID-19 outbreak on air quality in Bangladesh: a spatiotemporal analysis

In Bangladesh, a nationwide lockdown was imposed on 26 March 2020, due to the COVID-19 pandemic. Due to restricted emissions, it was hypothesized that the air quality has been improved during lockdown throughout the country. The study is intended to assess the impact of nationwide lockdown measures on air quality in Bangladesh. We analyzed satellite data for four different air pollutants (NO2, SO2, CO, and O3) to assess the changes in the atmospheric concentrations of pollutants in major cities as well as across the country. In this study, the concentrations of NO2, SO2, CO, and O3 from 1 February to 30 May of the year 2019 and 2020 were analyzed. The average SO2 and NO2 concentrations were decreased by 43 and 40%, respectively, while tropospheric O3 were found to be increased with a maximum of > 7%. Among the major cities, Dhaka, Gazipur, Chattogram, and Narayanganj were found to be more influenced by the restricted emissions. In Dhaka, NO2 and SO2 concentrations were decreased approximately by 69 and 67%, respectively. Our analysis reveals that NO2 concentrations are highly correlated with the regional COVID-19 cases (r = 0.74). The study concludes that the lockdown measures significantly reduced air pollution because of reduced vehicular and industrial emissions in Bangladesh.

Islam, Md Sariful, et al. "Impacts of nationwide lockdown due to COVID-19 outbreak on air quality in Bangladesh: a spatiotemporal analysis." Air Quality, Atmosphere & Health (2020): 1-13.

Impact of COVID -19 pandemic lockdown on distribution of inorganic pollutants in selected cities of Nigeria

The COVID-19 global pandemic has necessitated some drastic measures to curb its spread. Several countries around the world instituted partial or total lockdown as part of the control measures for the pandemic. This presented a unique opportunity to study air pollution under reduced human activities. In this study, we investigated the impact of the lockdown on air pollution in three highly populated and industrious cities in Nigeria. Compared with historical mean values, NO2 levels increased marginally by 0.3% and 12% in Lagos and Kaduna respectively. However, the city of Port Harcourt saw a decrease of 1.1% and 215.5% in NO2 and SO2 levels respectively. Elevated levels of O3 were observed during the period of lockdown. Our result suggests that there are other sources of air pollution apart from transportation and industrial sources. Our findings showed that the COVID-19-induced lockdown was responsible for a decrease in NO2 levels in two of the locations studied. These results presents an opportunity for country wide policies to mitigate the impact of air pollution on the health of citizens.

Fuwape, I. A., C. T. Okpalaonwuka, and S. T. Ogunjo. "Impact of COVID-19 pandemic lockdown on distribution of inorganic pollutants in selected cities of Nigeria." Air Quality, Atmosphere & Health (2020): 1-7.

Impact of the COVID-19 outbreak on air pollution levels in East Asia

This study leverages satellite remote sensing to investigate the impact of the coronavirus outbreak and the resulting lockdown of public venues on air pollution levels in East Asia. We analyze data from the Sentinel-5P and the Himawari-8 satellites to examine concentrations of NO2, HCHO, SO2, and CO, and the aerosol optical depth (AOD) over the BTH, Wuhan, Seoul, and Tokyo regions in February 2019 and February 2020. Results show that most of the concentrations of pollutants are lower than those of February 2019. Compared to other pollutants, NO2 experienced the most significant reductions by almost 54%, 83%, 33%, and 19% decrease in BTH, Wuhan, Seoul, and Tokyo, respectively. The greatest reductions in pollutants occurred in Wuhan, with a decrease of almost 83%, 11%, 71%, and 4% in the column densities of NO2, HCHO, SO2, and CO, respectively, and a decrease of about 62% in the AOD. Although NO2, CO, and formaldehyde concentrations decreased in the Seoul and Tokyo metropolitan areas compared to the previous year, concentrations of SO2 showed an increase in these two regions due to the effect of transport from polluted upwind regions. We also show that meteorological factors were not the main reason for the dramatic reductions of pollutants in the atmosphere. Moreover, an investigation of the HCHO/NO2 ratio shows that in many regions of East China, particularly in Wuhan, ozone production in February 2020 is less NOX saturated during the daytime than it was in February 2019. With large reductions in the concentrations of NO2 during lockdown situations, we find that significant increases in surface ozone in East China from February 2019 to February 2020 are likely the result of less reaction of NO and O3 caused by significantly reduced NOX concentrations and less NOX saturation in East China during the daytime.

Ghahremanloo, Masoud, et al. "Impact of the COVID-19 outbreak on air pollution levels in East Asia." Science of The Total Environment (2020): 142226.

How Did Distribution Patterns of Particulate Matter Air Pollution (PM2.5 and PM10) Change in China during the COVID-19 Outbreak: A Spatiotemporal Investigation at Chinese City-Level

Due to the suspension of traffic mobility and industrial activities during the COVID-19, particulate matter (PM) pollution has decreased in China. However, rarely have research studies discussed the spatiotemporal pattern of this change and related influencing factors at city-scale across the nation. In this research, the clustering patterns of the decline rates of PM2.5 and PM10 during the period from 20 January to 8 April in 2020, compared with the same period of 2019, were investigated using spatial autocorrelation analysis. Four meteorological factors and two socioeconomic factors, i.e., the decline of intra-city mobility intensity (dIMI) representing the effect of traffic mobility and the decline rates of the secondary industrial output values (drSIOV), were adopted in the regression analysis. Then, multi-scale geographically weighted regression (MGWR), a model allowing the particular processing scale for each independent variable, was applied for investigating the relationship between PM pollution reductions and influencing factors. For comparison, ordinary least square (OLS) regression and the classic geographically weighted regression (GWR) were also performed. The research found that there were 16% and 20% reduction of PM2.5 and PM10 concentration across China and significant PM pollution mitigation in central, east, and south regions of China. As for the regression analysis results, MGWR outperformed the other two models, with R2 of 0.711 and 0.732 for PM2.5 and PM10, respectively. The results of MGWR revealed that the two socioeconomic factors had more significant impacts than meteorological factors. It showed that the reduction of traffic mobility caused more relative declines of PM2.5 in east China (e.g., cities in Jiangsu), while it caused more relative declines of PM10 in central China (e.g., cities in Henan). The reduction of industrial operation had a strong relationship with the PM10 drop in northeast China. The results are crucial for understanding how the decline pattern of PM pollution varied spatially during the COVID-19 outbreak, and it also provides a good reference for air pollution control in the future.

Fan, Zhiyu, et al. "How Did Distribution Patterns of Particulate Matter Air Pollution (PM2. 5 and PM10) Change in China during the COVID-19 Outbreak: A Spatiotemporal Investigation at Chinese City-Level." International Journal of Environmental Research and Public Health 17.17 (2020): 6274.

Air Quality Change in Seoul, South Korea under COVID-19 Social Distancing: Focusing on PM2.5

Seoul, the most populous city in South Korea, has been practicing social distancing to slow down the spread of coronavirus disease 2019 (COVID-19). Fine particulate matter (PM2.5) and other air pollutants measured in Seoul over the two 30 day periods before and after the start of social distancing are analyzed to assess the change in air quality during the period of social distancing. The 30 day mean PM2.5 concentration decreased by 10.4% in 2020, which is contrasted with an average increase of 23.7% over the corresponding periods in the previous 5 years. The PM2.5 concentration decrease was city-wide and more prominent during daytime than at nighttime. The concentrations of carbon monoxide (CO) and nitrogen dioxide (NO2) decreased by 16.9% and 16.4%, respectively. These results show that social distancing, a weaker forcing toward reduced human activity than a strict lockdown, can help lower pollutant emissions. At the same time, synoptic conditions and the decrease in aerosol optical depth over the regions to the west of Seoul support that the change in Seoul's air quality during the COVID-19 social distancing can be interpreted as having been affected by reductions in the long-range transport of air pollutants as well as local emission reductions.

Han, Beom-Soon, et al. "Air Quality Change in Seoul, South Korea under COVID-19 Social Distancing: Focusing on PM2. 5." International Journal of Environmental Research and Public Health 17.17 (2020): 6208.

COVID-19 lockdown and its impact on tropospheric NO2 concentrations over India using satellite-based data

The World Health Organization has declared the COVID-19 pandemic a global public health emergency. Many countries of the world, including India, closed their borders and imposed a nationwide lockdown. In India, the lockdown was declared on March 24 for 21 days (March 25–April 14, 2020) and was later extended until May 3, 2020. During the lockdown, all major anthropogenic activities, which contribute to atmospheric pollution (such as industries, vehicles, and businesses), were restricted. The current study examines the impact of the lockdown on tropospheric NO2 concentrations. Satellite-based ozone monitoring instrument sensor data were analyzed in order to investigate the variations in tropospheric NO2 concentrations. The results showed that from March 1 to 21, 2020, the average tropospheric NO2 concentration was 214.4 ×1013 molecule cm-2 over India, and it subsequently decreased by 12.1% over the next four weeks. An increase of 0.8% in tropospheric NO2 concentrations was observed for the same period in 2019 and hence, the reduced tropospheric NO2 concentrations can be attributed to restricted anthropogenic activities during the lockdown. In the absence of significant activities, the contribution of various sources was estimated, and the emissions from biomass burning were identified as a major source of tropospheric NO2 during the lockdown. The findings of this study provide an opportunity to understand the mechanism of tropospheric NO2 emissions over India, in order to improve air quality modeling and management strategies.

Biswal, Akash, et al. "COVID-19 lockdown and its impact on tropospheric NO2 concentrations over India using satellite-based data." Heliyon 6.9 (2020): e04764.

The impact of COVID-19 control measures on air quality in China

The outbreak of Coronavirus Disease 2019 (COVID-19) in China in January 2020 prompted substantial control measures including social distancing measures, suspension of public transport and industry, and widespread cordon sanitaires ('lockdowns'), that have led to a decrease in industrial activity and air pollution emissions over a prolonged period. We use a 5 year dataset from China's air quality monitoring network to assess the impact of control measures on air pollution. Pollutant concentration time series are decomposed to account for the inter-annual trend, seasonal cycles and the effect of Lunar New Year, which

coincided with the COVID-19 outbreak. Over 2015–2019, there were significant negative trends in particulate matter (PM2.5, -6% yr-1) and sulphur dioxide (SO2, -12% yr-1) and nitrogen dioxide (NO2, -2.2% yr-1) whereas there were positive trends in ozone (O3, +2.8% y3-1). We quantify the change in air quality during the LNY holiday week, during which pollutant concentrations increase on LNY's day, followed by reduced concentrations in the rest of the week. After accounting for interannual trends and LNY we find NO2 and PM concentrations were significantly lower during the lockdown period than would be expected, but there were no significant impacts on O3. Largest reductions occurred in NO2, with concentrations 27.0% lower on average across China, during the lockdown. Average concentrations of PM2.5 and PM10 across China were respectively 10.5% and 21.4% lower during the lockdown period. The largest reductions were in Hubei province, where NO2 concentrations were 50.5% lower than expected during the lockdown. Concentrations of affected pollutants returned to expected levels during April, after control measures were relaxed.

Silver, Ben, et al. "The impact of COVID-19 control measures on air quality in China." Environmental Research Letters 15.8 (2020): 084021.

Associations between Air Pollution and COVID-19 epidemic during quarantine period in China

The coronavirus disease (COVID-19) has become a global public health threaten. A series of strict prevention and control measures were implemented in China, contributing to the improvement of air quality. In this study, we described the trend of air pollutant concentrations and the incidence of COVID-19 during the epidemic and applied generalized additive models (GAMs) to assess the association between short-term exposure to air pollution and daily confirmed cases of COVID-19 in 235 Chinese cities. Disease progression based on both onset and report dates as well as control measures as potential confounding were considered in the analyses. We found that stringent prevention and control measures intending to mitigate the spread of COVID-19, contributed to a significant decline in the concentrations of air pollutants except ozone (O3). Significant positive associations of short-term exposure to air pollutants, including particulate matter with diameters ≤2.5μm (PM2.5), particulate matter with diameters ≤10μm (PM10), and nitrogen dioxide (NO2) with daily new confirmed cases were observed during the epidemic. Per interquartile range (IQR) increase in PM2.5 (lag0-15), PM10 (lag0-15), and NO2 (lag0-20) were associated with a 7% [95% confidence interval (CI): (4 - 9)], 6% [95% CI: (3 - 8)], and 19% [95% CI: (13 - 24)] increase in the counts of daily onset cases, respectively. Our results suggest that there is a statistically significant association between ambient air pollution and the spread of COVID-19. Thus, the quarantine measures can not only cut off the transmission of virus, but also retard the spread by improving ambient air quality, which might provide implications for the prevention and control of COVID-19.

Zhang, Xinhan, et al. "Associations between Air Pollution and COVID-19 epidemic during quarantine period in China." Environmental Pollution (2020): 115897.

Uncertainty in the Impact of the COVID-19 Pandemic on Air Quality in Hong Kong, China

Strict social distancing rules are being implemented to stop the spread of COVID-19 pandemic in many cities globally, causing a sudden and extreme change in the transport activities. This offers a unique opportunity to assess the effect of anthropogenic activities on air quality and provides a valuable reference to the policymakers in developing air quality control measures and projecting their effectiveness. In this study, we evaluated the effect of the COVID-19 lockdown on the roadside and ambient air quality in Hong Kong, China, by comparing the air quality monitoring data collected in January–April 2020 with those in 2017–2019. The results showed that the roadside and ambient NO2, PM10, PM2.5, CO and SO2 were generally reduced in 2020 when comparing with the historical data in 2017–2019, while O3 was increased. However, the reductions during COVID-19 period (i.e., February–April) were not always higher than that during pre-COVID-19 period (i.e., January). In addition, there were large seasonal variations in the monthly

mean pollutant concentrations in every year. This study implies that one air pollution control measure may not generate obvious immediate improvements in the air quality monitoring data and its effectiveness should be evaluated carefully to eliminate the effect of seasonal variations.

Huang, Y. , Zhou, J. L. , Yu, Y. , Mok, W. C. , & Yam, Y. S. . (2020). Uncertainty in the impact of the covid-19 pandemic on air quality in hong kong, china. Atmosphere, 11(9), 914.

The Effect of the Covid-19 Lockdown on Air Quality in Three Italian Medium-Sized Cities

Despite the societal and economic impacts of the COVID-19 pandemic, the lockdown measures put in place by the Italian government provided an unprecedented opportunity to increase our knowledge of the effect transportation and industry-related emissions have on the air quality in our cities. This study assessed the effect of reduced emissions during the lockdown period, due to COVID-19, on air quality in three Italian cities, Florence, Pisa, and Lucca. For this study, we compared the concentration of particulate matter PM10, PM2.5, NO2, and O3 measured during the lockdown period, with values obtained in the same period of 2019. Our results show no evidence of a direct relationship between the lockdown measures implemented and PM reduction in urban centers, except in areas with heavy traffic. Consistent with recently published studies, we did, however, observe a significant decrease in NO2 concentrations among all the air-monitoring stations for each city in this study. Finally, O3 levels remained unchanged during the lockdown period. Of note, there were slight variations in the meteorological conditions for the same periods of different years. Our results suggest a need for further studies on the impact of vehicular traffic and industrial activities on PM air pollution, including adopting holistic source-control measures for improved air quality in urban environments.

Donzelli, Gabriele, et al. "The Effect of the Covid-19 Lockdown on Air Quality in Three Italian Medium-Sized Cities." Atmosphere 11.10 (2020): 1118.

Impact of lockdown on air quality over major cities across the globe during COVID-19 pandemic

In present study, the variation in concentration of key air pollutants such as PM2.5, PM10, NO2, SO2 and O3 during the pre-lockdown and post-lockdown phase has been investigated. In addition, the monthly concentration of air pollutants in March, April and May of 2020 is also compared with that of 2019 to unfold the effect of restricted emissions under similar meteorological conditions. To evaluate the global impact of COVID-19 on the air quality, ground-based data from 162 monitoring stations from 12 cities across the globe are analysed for the first time. The concentration of PM2.5, PM10 and NO2 were reduced by 20–34%, 24–47% and 32–64%, respectively, due to restriction on anthropogenic emission sources during lockdown. However, a lower reduction in SO2 was observed due to functional power plants. O3 concentration was found to be increased due to the declined emission of NO. Nevertheless, the achieved improvements were temporary as the pollution level has gone up again in cities where lockdown was lifted. The study might assist the environmentalist, government and policymakers to curb down the air pollution in future by implementing the strategic lockdowns at the pollution hotspots with minimal economic loss.

Kumari, Pratima, and Durga Toshniwal. "Impact of lockdown on air quality over major cities across the globe during COVID-19 pandemic." Urban Climate 34 (2020): 100719.

Impact of the COVID-19 Pandemic on the Air Quality in Delhi, India

The COVID-19 pandemic is one of the biggest health calamities that the world has faced, which has infected millions of people and lead to hundreds of thousands of deaths all over the world. It has impacted the economic, social and health aspects of the countries to quite an extreme level. But an indirect positive

impact can also be seen on the environment. In this paper, taking the example of Delhi, one of the most polluted cities of India, an analysis has been done to compare the levels of air pollutants (PM2.5, PM10, NOx and ozone) during the lockdown and the same period in the previous years. The study shows that the extent to which the industries, vehicles, power plants etc. release the air pollutants and severely impact the environment and human health. As during the lockdown when all such activities were either stopped or very much restricted, a reduction of almost 60% in the particulate matter pollution and up to 40% in the NOx pollution was observed while the ozone levels were reduced by 30-40% as compared to the same period during the previous two years. In the end, some suggestions have been made which can play some part to control air pollution once the lockdown is over

Goel, Apurva. "Impact of the COVID-19 Pandemic on the Air Quality in Delhi, India." Nature Environment and Pollution Technology 19.3 (2020): 1095-1103.

The Effects of COVID-19 Measures on Air Pollutant Concentrations at Urban and Traffic Sites in Istanbul

Since December 2019, most countries have been working to stop the spread of SARS-CoV-2, the virus responsible for COVID-19. These measures, which include restricting movement, have environmental consequences. This study assessed the impact of COVID-19 measures on air pollutant concentrations measured in urban areas and traffic stations on both the European and Asian sides of Istanbul during March 2020. Significant reductions in pollutants: 32–43% (PM10), 19–47% (PM2.5), 29–44% (NO2), 40–58% (CO) and 34–69% (SO2) were calculated. The clearest reductions at the traffic stations were in NO2 which originates primarily from vehicle exhaust. The reduction of NO2 at the traffic station on the European side was found higher comparing the Asian side. The average concentrations of NO2, PM2.5, PM10 and CO during peak traffic hours were significantly ($p < 0.01$) decreased under COVID-19 measures. The results indicate that due to the measures taken in Istanbul and across Turkey and to control the spread of the virus, anthropogenic activities such as industry, vehicle traffic and sea transport have decreased, and consequently, air pollution has been significantly reduced. These pollutant levels demonstrate the anthropogenic contribution to air pollution and can inform clean air actions in Istanbul and in others cities throughout the world.

Şahin, Ülkü Alver. "The Effects of COVID-19 Measures on Air Pollutant Concentrations at Urban and Traffic Sites in Istanbul." Aerosol and Air Quality Research 20 (2020): 1874-1885.

Impact of COVID-19 Containment Measures on Air Pollution in California

This study used space- and ground-based sensors in conjunction meteorological and traffic information to evaluate the impact of the COVID-19 containment measures on air pollution in California by comparing data from March–April 2020 to the similar period in 2019. Although significantly lower pollution levels were observed throughout the COVID-19 containment period in 2020 compared to 2019, our meteorological analysis found that periods of enhanced precipitation likely contributed to the cleaner environment over the Central Valley and southern California. Therefore, we focused our assessment on a 19-day period of drier conditions across the region. During this period, TROPOspheric Monitoring Instrument (TROPOMI) data revealed strong reductions in tropospheric NO2 of 40% in Los Angeles, 38% in Fresno, and about 20% in Bakersfield and San Francisco when compared to 2019. The reductions were mostly within about 10% of the decrease in vehicle miles traveled (VMT), which indicates that the decrease in traffic-related NOx due to the COVID-19 lockdown was an important driver of the NO2 reduction. Ozone Monitoring Instrument (OMI) data showed similar NO2 reductions to TROPOMI over Los Angeles during the lockdown, but drastically different results over the other cities where little to no reductions were observed. The close agreement between ground-based and TROPOMI observations indicated that a more accurate assessment of the impacts from the COVID-19 lockdown can be accomplished using TROPOMI

rather than OMI data, which is attributed to its improved resolution and sensitivity that can better characterize NO2 pollution associated with fine-scale emissions. Altogether, the space- and ground-based observations provide strong evidence that the containment measures led to NO2 reductions of around 35% in Los Angeles and Fresno and 25% in San Francisco and Bakersfield relative to 2019, along with decreases in PM2.5 and improved air quality at the surface.

Naeger, Aaron R., and Kelley Murphy. "Impact of COVID-19 Containment Measures on Air Pollution in California." Aerosol and Air Quality Research 20 (2020).

Indoor Air Pollution was Nonnegligible during COVID-19 Lockdown

COVID-19 spread globally in the past months and caused hundreds of thousands of people dead. Many countries took lockdown policy to restrict human activities and industry to slow down the virus spread. The implementation of stringent lockdown resulted in less traffic and industrial emissions, thus reduction of various ambient air pollutants were observed in urban areas. Considering people stayed longer time in indoor, the indoor air pollution (IAP) might play a more important role for human health during lockdown. People suffered from high possibility of IAP exposure risk increase during lockdown as they almost stayed at home the whole day. Unfortunately, available studies on IAP and its health impact during this period were rare compared with those on ambient air. By this, more investigations should be performed to estimate the impact of global COVID-19 lockdown on human health in the future.

Du, Wei, and Gehui Wang. "Indoor Air Pollution was Nonnegligible during COVID-19 Lockdown." Aerosol and Air Quality Research 20 (2020).

Spatiotemporal Variations and Contributing Factors of Air Pollutant Concentrations in Malaysia during Movement Control Order due to Pandemic COVID-19

The restriction of daily and economic-related activities due to COVID-19 pandemic via lockdown order has been reported to improve air quality. This study evaluated temporal and spatial variations of four major air pollutant concentrations across Malaysia before (March 4, 2020–March 17, 2020) and during the implementation of different phases of Movement Control Order (MCO) (March 18, 2020–May 12, 2020) from 65 official regulatory air quality stations. Results showed that restriction in daily and economic activities has remarkably reduced the air quality in all sub-urban, urban, and industrial settings with relatively small contributions from meteorological conditions. Overall, compared to before MCO, average concentrations of PM2.5, CO, and NO2 reduced by 23.1%, 21.74%, and 54.0%, respectively, while that of SO2 was constant. The highest reduction of PM2.5, CO, and NO2 were observed in stations located in urban setting, where 63% stations showed significant reduction ($p < 0.05$) for PM2.5 and CO, while all stations showed significant reduction in NO2 concentrations. It was also revealed that 70.5% stations recorded lower concentrations of PM2.5 during MCO compared to before MCO, despite that high numbers of local hotspots were observed simultaneously from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS). Spatial analysis showed that the northern part of Peninsular had the highest significant reduction of PM2.5, while the highest of NO2 and CO reduction were found in stations located in the central region. All pollutants exhibit similar diurnal trends when compared between pre- and during MCO although significant lower readings were observed during MCO. This study gives confidence to regulatory body; the enforcement of strict air pollution prevention and control policies could help in reducing pollution.

Ash'aari, Zulfa Hanan, et al. "Spatiotemporal Variations and Contributing Factors of Air Pollutant Concentrations in Malaysia during Movement Control Order due to Pandemic COVID-19." Aerosol and Air Quality Research 20 (2020).

Airborne particulate matter, population mobility and COVID-19: a multi-city study in China

Coronavirus disease 2019 (COVID-19) is an emerging infectious disease, which has caused numerous deaths and health problems worldwide. This study aims to examine the effects of airborne particulate matter (PM) pollution and population mobility on COVID-19 across China. We obtained daily confirmed cases of COVID-19, air particulate matter (PM2.5, PM10), weather parameters such as ambient temperature (AT) and absolute humidity (AH), and population mobility scale index (MSI) in 63 cities of China on a daily basis (excluding Wuhan) from January 01 to March 02, 2020. Then, the Generalized additive models (GAM) with a quasi-Poisson distribution were fitted to estimate the effects of PM10, PM2.5 and MSI on daily confirmed COVID-19 cases. We found each 1 unit increase in daily MSI was significantly positively associated with daily confirmed cases of COVID-19 in all lag days and the strongest estimated RR (1.21, 95% CIs:1.14 ~ 1.28) was observed at lag 014. In PM analysis, we found each 10 μg/m3 increase in the concentration of PM10 and PM2.5 was positively associated with the confirmed cases of COVID-19, and the estimated strongest RRs (both at lag 7) were 1.05 (95% CIs: 1.04, 1.07) and 1.06 (95% CIs: 1.04, 1.07), respectively. A similar trend was also found in all cumulative lag periods (from lag 01 to lag 014). The strongest effects for both PM10 and PM2.5 were at lag 014, and the RRs of each 10 μg/m3 increase were 1.18 (95% CIs:1.14, 1.22) and 1.23 (95% CIs:1.18, 1.29), respectively. Population mobility and airborne particulate matter may be associated with an increased risk of COVID-19 transmission.

Wang, Bo, et al. "Airborne particulate matter, population mobility and COVID-19: a multi-city study in China." BMC public health 20.1 (2020): 1-10.

How air quality and COVID-19 transmission change under different lockdown scenarios? A case from Dhaka city, Bangladesh

The transmission of novel coronavirus (COVID-19) can be reduced by implementing a lockdown policy, which has also been proven as an effective control measure for air pollution in the urban cities. In this study, we applied ground- and satellite-based data of five criteria air pollutants (PM2.5, NO2, SO2, O3, and CO) and meteorological factors from March 8 to May 15, 2020 (before, partial-, and full-lockdown). The generalized additive models (GAMs), wavelet coherence, and random forest (RF) model were employed to explore the relationship between air quality indicators and COVID-19 transmission in Dhaka city. Results show that overall, 26, 20.4, 17.5, 9.7 and 8.8% declined in PM 2.5, NO2, SO2, O3, and CO concentrations, respectively, in Dhaka City during the partial and full lockdown compared to the period before the lockdown. The implementation of lockdown policy for containing COVID-19 transmission played a crucial role in reducing air pollution. The findings of wavelet coherence and partial wavelet coherence demonstrate no standalone coherence, but interestingly, multiple wavelet coherence indicated a strong short-term coherence among air pollutants and meteorological factors with the COVID-19 outbreak. Outcomes of GAMs indicated that an increase of 1-unit in long-term exposure to O3 and CO (lag1) was associated with a 2.9% (95% CI: −0.3%, −5.6%), and 53.9% (95% CI: 0.2%, −107.9%) decreased risk of COVID-19 infection rate during the full-lockdown period. Whereas, COVID-19 infection and MT (mean temperature) are modulated by a peak during full-lockdown, which is mostly attributed to contact transmission in Dhaka city. RF model revealed among the parameters being studied, MT, RH (relative humidity), and O3 were the dominant factors that could be associated with COVID-19 cases during the study period. The outcomes reported here could elucidate the effectiveness of lockdown scenarios for COVID-19 containment and air pollution control in Dhaka city.

Rahman, Md Siddiqur, et al. "How air quality and COVID-19 transmission change under different lockdown scenarios? A case from Dhaka city, Bangladesh." Science of The Total Environment (2020): 143161.

Spatio-temporal assessment of ambient air quality, their health effects and improvement during COVID-19 lockdown in one of the most polluted cities of India

The present work aims to investigate seasonal variations in air pollution levels in Lucknow and assess the ambient air quality of the city together with highlighting the health impacts of major pollutants like PM10, PM2.5, SO2, NO2, Pb, Ni and aerosols from 2010 to 2019. The maximum and minimum values of PM10, PM2.5, SO2, NO2, Pb and Ni were found to be 270.75 and 122.45 µg/m3, 124.95 and 95.52 µg/m3, 25.60 and 8.05 µg/m3, 75.65 and 23.85 µg/m3, 0.66 and 0.03 µg/m3 and 0.07 and 0.01 ng/m3, respectively. Health impact of particulate matter has also been assessed with AirQ+, and it was estimated that long-term exposure of PM10 was attributed to between 37 and 48% for post-neonatal (age 1–12 months) mortality rate due to all causes, whereas long-term attributable proportions in mortality due to exposure of PM2.5 were to about 19 to 28% from all causes. Further, an attempt has also been made to evaluate the impact of lockdown amid COVID-19 on the ambient air quality of Lucknow. During the lockdown, PM2.5 levels reduced by 65% (at Gomti Nagar), 23% (at central school), 79% (at Lalbagh) and 35% (at Talkatora), due to which, air quality index of Gomti Nagar came down to 43, well below 50 which falls in the healthy range. NO2 levels also came down. However, levels of SO2 did not show significant reduction. Correlating the data between aerosol optical depth and Angstrom exponent by Pearson correlation analysis revealed a significant positive correlation ($r = 0.65$, $P < 0.001$).

Verma, Pradeep Kumar, et al. "Spatio-temporal assessment of ambient air quality, their health effects and improvement during COVID-19 lockdown in one of the most polluted cities of India." Environmental Science and Pollution Research (2020): 1-16.

São Paulo's atmospheric pollution reduction and its social isolation effect, Brazil

Since January 2020, studies report reductions in air pollution among several countries due to social isolation measures, which have been adopted in order to contain the coronavirus outbreak progress (COVID-19). This study aims to evaluate the change in the atmospheric pollution levels by NO and NO2 in São Paulo City for the social isolation period. The NO and NO2 hourly concentrations were obtained through air quality monitoring stations from CETESB, from January 14, 2020 to April 12, 2020. Mann-Kendall and the Pettitt tests were performed in the air pollutant time series. We observed an overall negative trend in all stations, indicating a decreasing temporal pattern in concentrations. Regarding NO, the highest absolute decrease rates were observed in the Congonhas (− 6.39 µg m−3 month−1) and Marginal Tietê (− 6.19 µg m−3 month−1) stations; regarding NO2, the highest rates were observed in the Marginal Tietê (− 4.45 µg m−3 month−1) and Cerqueira César (− 4.34 µg m−3 month−1) stations. In addition, we identified a turning point in the NO and NO2 series trends that occurred close to the start date of the social isolation period (March 20, 2020). Moreover, from statistical analysis, it was found that NO2 is a suitable surrogate for monitoring economic activities during social isolation periods. Thus, we concluded that social isolation measures implemented on March 20, 2020 caused significant changes in the air pollutant concentrations in the city of São Paulo (as high as − 200% in NO2 levels).

Rosse, Vinicius Possato, et al. "São Paulo's atmospheric pollution reduction and its social isolation effect, Brazil." Air Quality, Atmosphere & Health (2020): 1-10.

Dynamic model to predict the association between air quality, COVID-19 cases, and level of lockdown

Studies have reported significant reductions in air pollutant levels due to the COVID-19 outbreak worldwide global lockdowns. Nevertheless, all of the reports are limited compared to data from the same period over the past few years, providing mainly an overview of past events, with no future predictions. Lockdown level can be directly related to the number of new COVID-19 cases, air pollution, and economic

restriction. As lockdown status varies considerably across the globe, there is a window for mega-cities to determine the optimum lockdown flexibility. To that end, firstly, we employed four different Artificial Neural Networks (ANN) to examine the compatibility to the original levels of CO, O3, NO2, NO, PM2.5, and PM10, for São Paulo City, the current Pandemic epicenter in South America. After checking compatibility, we simulated four hypothetical scenarios: 10%, 30%, 70%, and 90% lockdown to predict air pollution levels. To our knowledge, ANN have not been applied to air pollution prediction by lockdown level. Using a limited database, the Multilayer Perceptron neural network has proven to be robust (with Mean Absolute Percentage Error ~ 30%), with acceptable predictive power to estimate air pollution changes. We illustrate that air pollutant levels can effectively be controlled and predicted when flexible lockdown measures are implemented. The models will be a useful tool for governments to manage the delicate balance among lockdown, number of COVID-19 cases, and air pollution.

Tadano, Yara S., et al. "Dynamic model to predict the association between air quality, COVID-19 cases, and level of lockdown." Environmental Pollution (2020): 115920.

Ozone pollution mitigation in guangxi (south China) driven by meteorology and anthropogenic emissions during the COVID-19 lockdown

With the implementation of COVID-19 restrictions and consequent improvement in air quality due to the nationwide lockdown, ozone (O3) pollution was generally amplified in China. However, the O3 levels throughout the Guangxi region of South China showed a clear downward trend during the lockdown. To better understand this unusual phenomenon, we investigated the characteristics of conventional pollutants, the influence of meteorological and anthropogenic factors quantified by a multiple linear regression (MLR) model, and the impact of local sources and long-range transport based on a continuous emission monitoring system (CEMS) and the HYSPLIT model. Results show that in Guangxi, the conventional pollutants generally declined during the COVID-19 lockdown period (January 24 to February 9, 2020) compared with their concentrations during 2016–2019, while O3 gradually increased during the resumption (10 February to April 2020) and full operation periods (May and June 2020). Focusing on Beihai, a typical Guangxi region city, the correlations between the daily O3 concentrations and six meteorological parameters (wind speed, visibility, temperature, humidity, precipitation, and atmospheric pressure) and their corresponding regression coefficients indicate that meteorological conditions were generally conducive to O3 pollution mitigation during the lockdown. A 7.84 μg/m3 drop in O3 concentration was driven by meteorology, with other decreases (4.11 μg/m3) explained by reduced anthropogenic emissions of O3 precursors. Taken together, the lower NO2/SO2 ratios (1.25–2.33) and consistencies between real-time monitored primary emissions and ambient concentrations suggest that, with the closure of small-scale industries, residual industrial emissions have become dominant contributors to local primary pollutants. Backward trajectory cluster analyses show that the slump of O3 concentrations in Southern Guangxi could be partly attributed to clean air mass transfer (24–58%) from the South China Sea. Overall, the synergistic effects of the COVID-19 lockdown and meteorological factors intensified O3 reduction in the Guangxi region of South China.

Fu, Shuang, et al. "Ozone pollution mitigation in Guangxi (South China) driven by meteorology and anthropogenic emissions during the COVID-19 lockdown." Environmental Pollution (2020): 115927.

Impacts of the COVID-19 lockdown on air quality and its association with human mortality trends in megapolis Mexico City

Mexico City is the second most populated city in Latin America, and it went through two partial lockdowns between April 1 and May 31, 2020, for reducing the COVID-19 propagation. The present study assessed air quality and its association with human mortality rates during the lockdown by estimating changes

observed in air pollutants (CO, NO2, O3, SO2, PM10 and PM2.5) between the lockdown (April 1–May 31) and prelockdown (January 1–March 31) periods, as well as by comparing the air quality data of lockdown period with the same interval of previous 5 years (2015–2019). Concentrations of NO2 (− 29%), SO2 (− 55%) and PM10 (− 11%) declined and the contents of CO (+ 1.1%), PM2.5 (+ 19%) and O3 (+ 63%) increased during the lockdown compared to the prelockdown period. This study also estimated that NO2, SO2, CO, PM10 and PM2.5 reduced by 19–36%, and O3 enhanced by 14% compared to the average of 2015–2019. Reduction in traffic as well as less emission from vehicle exhausts led to remarkable decline in NO2, SO2 and PM10. The significant positive associations of PM2.5, CO and O3 with the numbers of COVID-19 infections and deaths, however, underscored the necessity to enforce air pollution regulations to protect human health in one of the important cities of the northern hemisphere.

Kutralam-Muniasamy, Gurusamy, et al. "Impacts of the COVID-19 lockdown on air quality and its association with human mortality trends in megapolis Mexico City." Air Quality, Atmosphere & Health (2020): 1-10.

Impact of the COVID-19 Pandemic Lockdown on Air Pollution in 20 Major Cities around the World

In order to fight against the spread of COVID-19, the most hard-hit countries in the spring of 2020 implemented different lockdown strategies. To assess the impact of the COVID-19 pandemic lockdown on air quality worldwide, Air Quality Index (AQI) data was used to estimate the change in air quality in 20 major cities on six continents. Our results show significant declines of AQI in NO2, SO2, CO, PM2.5 and PM10 in most cities, mainly due to the reduction of transportation, industry and commercial activities during lockdown. This work shows the reduction of primary pollutants, especially NO2, is mainly due to lockdown policies. However, preexisting local environmental policy regulations also contributed to declining NO2, SO2 and PM2.5 emissions, especially in Asian countries. In addition, higher rainfall during the lockdown period could cause decline of PM2.5, especially in Johannesburg. By contrast, the changes of AQI in ground-level O3 were not significant in most of cities, as meteorological variability and ratio of VOC/NOx are key factors in ground-level O3 formation.

Fu, Franck, Kathleen L. Purvis-Roberts, and Branwen Williams. "Impact of the COVID-19 Pandemic Lockdown on Air Pollution in 20 Major Cities around the World." Atmosphere 11.11 (2020): 1189.

Disparity in ozone trends under COVID-19 lockdown in a closely located coastal and hillocky metropolis of India

The outbreak of COVID-19, a global health challenge faced by countries worldwide, led to a lockdown in India, thereby bringing down the emissions of various air pollutants. Here, we discuss the behaviour of surface ozone (O3) concentrations and its precursors, oxides of nitrogen (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) at two Indian megacities namely Mumbai and Pune, closely located yet vastly differing in meteorology due to their locations. Although levels of CO, NO2, and VOC declined sharply after the lockdown in both cities, with NO2 showing the highest reduction, ozone concentration in Pune remained unaffected, whereas Mumbai exhibited a mixed trend, touching even a maximum in between the lockdown. On a diurnal scale, the magnitude of O3 levels during the lockdown period is higher at almost all hours in Mumbai, and in Pune, it is almost identical except during night hours when it is marginally higher in the lockdown period as compared to the normal period. On a whole, the pollution levels were brought down significantly which can be used as a benchmark in the future for the implementation of policies related to air quality management and emission control in Indian megacities by the policymakers. These results also can pave a way for the scientific community for local air quality modelling.

Korhale, Nikhil, Vrinda Anand, and Gufran Beig. "Disparity in ozone trends under COVID-19 lockdown in a closely located coastal and hillocky metropolis of India." Air Quality, Atmosphere & Health (2020): 1-10.

Impacts of short-term lockdown during COVID-19 on air quality in Egypt

COVID-19 is a pandemic disease that is actively spread over the globe in a few months. Most of the Nations took the appropriate measures including lockdown to reduce the risk of spreading and safe human health and life. Egypt took the measures of partial and complete lockdown from 15th March till 30th June 2020. Such short-term lockdown has had a significant impact on the reduction of emissions from transportation, industrial and human activities. This research used multi-data sensors from space to map the changes of air quality over Egypt in the first 6 months from January to June 2020 due to the lockdown and compare with previous years of 2018 and 2019. It is clearly observed that the air quality over the whole country is improved as a result of reducing pollutants emissions, with NO2 reduced by 45.5%, CO emissions reduced by 46.23%, Ozone concentration decreased by about 61.1%, and AOD reduced by 68.5% compared to the previous 2 years. It is found that the lockdown is an effective mitigation measure against air pollution to improve air quality and reduce the air pollution that creates pressure on the human health and health system. It might be difficult to implement long lockdown, as a mitigation measure, due to its direct impact on social and economic needs. However, we recommend a complete lockdown for 2–3 days (long weekend) every at least 2-3 months, on national and/or global level, which will significantly enhance our air quality and improve the health environment of the planet.

Abou El-Magd, Islam, and Naglaa Zanaty. "Impacts of Short-Term Lockdown during COVID-19 on Air Quality in Egypt." The Egyptian Journal of Remote Sensing and Space Science (2020).

AIR POLLUTION COVID-19 HEALTH LINK

Exposure to air pollution and COVID-19 mortality in the United States

Background: United States government scientists estimate that COVID-19 may kill between 100,000 and 240,000 Americans. The majority of the pre-existing conditions that increase the risk of death for COVID-19 are the same diseases that are affected by long-term exposure to air pollution. We investigate whether long-term average exposure to fine particulate matter (PM2.5) increases the risk of COVID-19 deaths in the United States. Methods: Data was collected for approximately 3,000 counties in the United States (98% of the population) up to April 04, 2020. We fit zero-inflated negative binomial mixed models using county-level COVID-19 deaths as the outcome and county level long-term average of PM2.5 as the exposure. We adjust by population size, hospital beds, number of individuals tested, weather, and socioeconomic and behavioral variables including, but not limited to obesity and smoking. We include a random intercept by state to account for potential correlation in counties within the same state.

Results: We found that an increase of only 1 µg/m3 in PM2.5 is associated with a 15% increase in the COVID-19 death rate, 95% confidence interval (CI) (5%, 25%). Results are statistically significant and robust to secondary and sensitivity analyses.

Conclusions: A small increase in long-term exposure to PM2.5 leads to a large increase in COVID-19 death rate, with the magnitude of increase 20 times that observed for PM2.5 and all-cause mortality. The study results underscore the importance of continuing to enforce existing air pollution regulations to protect human health both during and after the COVID-19 crisis.

Xiao Wu, Rachel C. Nethery, Benjamin M. Sabath, Danielle Braun, Francesca Dominici, "Exposure to air pollution and COVID-19 mortality in the United States." medRxiv (2020). https://www.medrxiv.org/content/10.1101/2020.04.05.20054502v1

Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy?

This paper investigates the correlation between the high level of Severe Acute Respiratory Syndrome CoronaVirus 2 (SARS-CoV-2) lethality and the atmospheric pollution in Northern Italy. Indeed, Lombardy and Emilia Romagna are Italian regions with both the highest level of virus lethality in the world and one of Europe's most polluted area. Based on this correlation, this paper analyzes the possible link between pollution and the development of acute respiratory distress syndrome and eventually death. We provide evidence that people living in an area with high levels of pollutant are more prone to develop chronic respiratory conditions and suitable to any infective agent. Moreover, a prolonged exposure to air pollution leads to a chronic inflammatory stimulus, even in young and healthy subjects. We conclude that the high level of pollution in Northern Italy should be considered an additional co-factor of the high level of lethality recorded in that area.

Conticini, Edoardo, Bruno Frediani, and Dario Caro. "Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy?." Environmental Pollution (2020): 114465.

Does Air Pollution Influence COVID-19 Outbreaks?

SARS-CoV-2 is highly transmissible (with more than 1.3 million people infected in the world at the time of this writing) and lethal (more than 76,000 reported deaths at present). Exposure to air pollution could increase vulnerability and have detrimental effects on the prognosis of patients affected by the COVID-19. However, the relative weight of air pollution, compared to other confounders, is still to be determined.

Caution should be used in translating high values of conventional metrics, such as PM2.5 and PM10 concentrations, into a direct measure of vulnerability. Airborne transmission mediated by virus-laden aerosols emitted during expiration and speech is plausible in specific environments. Current knowledge indicates a low probability in outdoor environments and an increase in probability in specific indoor environments, like hospitals and areas where patients are quarantined. In these environments, it is advisable to mitigate the risk for vulnerable people via using periodic ventilation of environments, decontaminations of surfaces and air conditioning systems, and appropriate technologies for mechanical ventilation/conditioning in order to limit the circulation of virus-laden bioaerosols in air.

The stakes for the world are enormous, and the results of robust research studies are urgently needed in order to provide information that could help in developing strategies for facing the current pandemic as well as future pandemics. Our recommendations for future research focus on (but are no limited to) the investigation, both outdoors and indoors, of airborne transmission routes, lifetimes and dynamics, dosimetry and infection thresholds within the human body, and the physical, chemical, biological, toxicological, virological properties of virus-laden bioaerosol particles, with all of these factors properly adjusted for a wide number of potential confounders. This research should come from a multidisciplinary approach involving a strong collaboration between traditionally distinct disciplines of science, and in particular, virologists, epidemiologists, toxicologists, physicians, aerobiologists, aerosol scientists, and meteorologists.

Contini, D.; Costabile, F. Does Air Pollution Influence COVID-19 Outbreaks? Atmosphere 2020, 11, 377.

Evaluation of the potential relationship between Particulate Matter (PM) pollution and COVID-19 infection spread in Italy

In conclusion, the rapid COVID-19 infection spread observed in selected regions of Northern Italy is supposed be related to PM10 pollution due to airborne particles able to serve as carrier of pathogens. As

already highlighted in previous studies, it is recommended to take into account PM10 contribution and make policymakers aware of the need to take direct actions for pollution control.

Piazzalunga-Expert, Andrea. Evaluation of the potential relationship between Particulate Matter (PM) pollution and COVID-19 infection spread in Italy. mimeo, 2020.

Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality

Nitrogen dioxide (NO2) is an ambient trace-gas result of both natural and anthropogenic processes. Long-term exposure to NO2 may cause a wide spectrum of severe health problems such as hypertension, diabetes, heart and cardiovascular diseases and even death. The objective of this study is to examine the relationship between long-term exposure to NO2 and coronavirus fatality. The Sentinel-5P is used for mapping the tropospheric NO2 distribution and the NCEP/NCAR reanalysis for evaluating the atmospheric capability to disperse the pollution. The spatial analysis has been conducted on a regional scale and combined with the number of death cases taken from 66 administrative regions in Italy, Spain, France and Germany. Results show that out of the 4443 fatality cases, 3487 (78%) were in five regions located in north Italy and central Spain. Additionally, the same five regions show the highest NO2 concentrations combined with downwards airflow which prevent an efficient dispersion of air pollution. These results indicate that the long-term exposure to this pollutant may be one of the most important contributors to fatality caused by the COVID-19 virus in these regions and maybe across the whole world.

Ogen, Yaron. "Assessing nitrogen dioxide (NO2) levels as a contributing factor to the coronavirus (COVID-19) fatality rate." Science of The Total Environment (2020): 138605.

Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China

The novel coronavirus pneumonia, namely COVID-19, has become a global public health problem. Previous studies have found that air pollution is a risk factor for respiratory infection by carrying microorganisms and affecting body's immunity. This study aimed to explore the relationship between ambient air pollutants and the infection caused by the novel coronavirus. Daily confirmed cases, air pollution concentration and meteorological variables in 120 cities were obtained from January 23, 2020 to February 29, 2020 in China. We applied a generalized additive model to investigate the associations of six air pollutants (PM2.5, PM10, SO2, CO, NO2 and O3) with COVID-19 confirmed cases. We observed significantly positive associations of PM2.5, PM10, NO2 and O3 in the last two weeks with newly COVID-19 confirmed cases. A 10-μg/m3 increase (lag0–14) in PM2.5, PM10, NO2, and O3 was associated with a 2.24% (95% CI: 1.02 to 3.46), 1.76% (95% CI: 0.89 to 2.63), 6.94% (95% CI: 2.38 to 11.51), and 4.76% (95% CI: 1.99 to 7.52) increase in the daily counts of confirmed cases, respectively. However, a 10-μg/m3 increase (lag0–14) in SO2 was associated with a 7.79% decrease (95% CI: −14.57 to −1.01) in COVID-19 confirmed cases. Our results indicate that there is a significant relationship between air pollution and COVID-19 infection, which could partially explain the effect of national lockdown and provide implications for the control and prevention of this novel disease.

Yongjian, Zhu, et al. "Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China." Science of The Total Environment (2020): 138704.

Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID

This study has two goals. The first is to explain the geo-environmental determinants of the accelerated diffusion of COVID-19 in Italy that is generating a high level of deaths. The second is to suggest a strategy to

cope with future epidemic threats having accelerated viral infectivity in society. Using data on N = 55 Italian province capitals, and data of infected individuals at as of April 7th, 2020, results reveal that the accelerate and vast diffusion of COVID-19 in North Italy has a high association with air pollution of cities measured with days exceeding the limits set for PM10 (particulate matter 10 µm or less in diameter) or ozone in previous years. In particular, hinterland cities with average higher number of days exceeding the limits set for PM10 (and a low intensity of wind speed) have a very high number of infected people on 7th April 2020 (arithmetic mean about 2200 infected, with average polluted days greater than 80), than coastal cities also having days of exceeding the limits set for PM10 or ozone but with high intensity of wind speed (arithmetic mean about 944.70 infected individuals, with about 60 average polluted days); moreover, cities having more than 100 days of air pollution (exceeding the limits set for PM10), they have a very high average number of infected people (about 3350 infected individuals, 7th April 2020), whereas cities having less than 100 days of air pollution, they have a lower average number of infected individuals (about 1014). The findings here also suggest that to minimize the impact of future epidemics similar to COVID-19, the max number of days per year in which Italian provincial capitals can exceed the limits set for PM10 or for ozone, considering their meteorological conditions, is about 48 days. Moreover, results here reveal that the explanatory variable of air pollution in cities under study seems to be a more important predictor in the initial phase of diffusion (on 17th March 2020, $b1 = 1.27$, $p < 0.001$) than interpersonal contacts ($b2 = 0.31$, $p < 0.05$). In the second phase of maturity of the transmission dynamics of COVID-19, air pollution reduces intensity (on 7th April 2020 with $b'1 = 0.81$, $p < 0.001$) also because of indirect effect of lockdown, whereas coefficient of transmission by interpersonal contacts has stability ($b'2 = 0.31$, $p < 0.01$). This result reveals that accelerated transmissions dynamics of COVID-19 is due to mainly to the mechanism of “air pollution-to-human transmission” rather than “human-to-human transmission”. Overall, then, transmission dynamics of viral infectivity, such as COVID-19, is due to systemic causes: general factors that are the same for all regions (e.g., biological characteristics of virus, incubation period, etc.) and specific factors which are different for each region (e.g., complex interaction between air pollution, meteorological conditions and biological characteristics of viral infectivity) and health level of individuals (habits, immune system, age, sex, etc.). Lessons learned for COVID-19 in the case study of Italy suggest that a proactive strategy to cope with future epidemics is to also apply especially an environmental and sustainable policy based on reduction of levels of air pollution mainly in hinterland and polluting cities- having low wind speed, high percentage of moisture and fog days-that seem to have an environment that may damage immune system of people and foster a fast transmission dynamics of viral infectivity in society. Hence, in the presence of polluting industrialization in regions that can trigger the mechanism of air pollution-to-human transmission dynamics of viral infectivity, this study must conclude that a comprehensive strategy to prevent future epidemics similar to COVID-19 has to be also designed in environmental and socioeconomic terms, that is also based on sustainability science and environmental science, and not only in terms of biology, healthcare and health sector.

Coccia, Mario. "Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID." Science of The Total Environment (2020): 138474.

Role of the chronic air pollution levels in the Covid-19 outbreak risk in Italy

After the initial outbreak in China, the diffusion in Italy of SARS-CoV-2 is exhibiting a clear regional trend with more elevated frequency and severity of cases in Northern areas. Among multiple factors possibly involved in such geographical differences, a role has been hypothesized for atmospheric pollution. We provide additional evidence on the possible influence of air quality, particularly in terms of chronicity of exposure on the spread viral infection in Italian regions. Actual data on Covid-19 outbreak in Italian provinces and corresponding long-term air quality evaluations, were obtained from Italian and European agencies, elaborated and tested for possible interactions. Our elaborations reveal that, beside concentrations, the chronicity of exposure may influence the anomalous variability of SARS-CoV-2 in Italy.

Data on distribution of atmospheric pollutants (NO2, O3, PM2.5 and PM10) in Italian regions during the last 4 years, days exceeding regulatory limits, and years of the last decade (2010–2019) in which the limits have been exceeded for at least 35 days, highlight that Northern Italy has been constantly exposed to chronic air pollution. Long-term air-quality data significantly correlated with cases of Covid-19 in up to 71 Italian provinces (updated April 27, 2020) providing further evidence that chronic exposure to atmospheric contamination may represent a favourable context for the spread of the virus. Pro-inflammatory responses and high incidence of respiratory and cardiac affections are well known, while the capability of this coronavirus to bind particulate matters remains to be established. Atmospheric and environmental pollution should be considered as part of an integrated approach for sustainable development, human health protection and prevention of epidemic spreads but in a long-term and chronic perspective, since adoption of mitigation actions during a viral outbreak could be of limited utility.

Fattorini, Daniele, and Francesco Regoli. "Role of the chronic air pollution levels in the Covid-19 outbreak risk in Italy." Environmental Pollution (2020): 114732.

Severe air pollution links to higher mortality in COVID-19 patients: the “double-hit” hypothesis

In areas of SARS-CoV-2 outbreak worldwide mean air pollutants concentrations vastly exceed the maximum limits. Chronic exposure to air pollutants have been associated with lung ACE-2 over-expression which is known to be the main receptor for SARS-coV2. The aim of this study was to analyse the relationship between air pollutants concentration (PM 2.5 and NO2) and COVID-19 outbreak, in terms of transmission, number of patients, severity of presentation and number of deaths. COVID-19 cases, ICU admissions and mortality rate were correlated with severity of air pollution in the Italian regions. The highest number of COVID-19 cases were recorded in the most polluted regions with patients presenting with more severe forms of the disease requiring ICU admission. In these regions, mortality was two-fold higher than the other regions. From the data available we propose a “double-hit hypothesis”: chronic exposure to PM 2.5 causes alveolar ACE-2 receptor overexpression. This may increase viral load in patients exposed to pollutants in turn depleting ACE-2 receptors and impairing host defences. High atmospheric NO2 may provide a second hit causing a severe form of SARS-CoV-19 in ACE-2 depleted lungs resulting in a worse outcome.

Frontera, Antonio, et al. "Severe air pollution links to higher mortality in COVID-19 patients: the “double-hit” hypothesis." Journal of Infection (2020).

First data analysis about possible COVID-19 virus airborne diffusion due to air particulate matter (PM): The case of Lombardy (Italy)

The severe cases of COVID-19 infections in Italy, and notably in Lombardy (mainly in Brescia and Bergamo areas), registered at the beginning of March 2020, occurred after a period of PM10 pollution, that exceeded the concentration of 50 µg/m3 (the attention limit) for several days. The two events were supposed to be correlated, also based on the limited information available about the new virus. Despite that clear indications about the role of particulate matter (PM) in the virus mechanism dispersion cannot be found in literature, some researchers supposed that PM can act as virus carrier, promoting its diffusion through the air.

This paper, for the first time, analyses the PM10 situation in Lombardy (from 10th February to March 27, 2020), several days before the sanitary emergency explosion. The data of the detected infection cases are reported and discussed parallelly. As a comparison, the situation of Piedmont, located near to the Lombardy is also presented. Data are reported for Brescia, Bergamo, Cremona, Lodi, Milano, Monza-Brianza, Pavia (Lombardy), Alessandria, Vercelli, Novara, Biella, Asti, and Torino (Piedmont). The results show that it is not possible to conclude that COVID-19 diffusion mechanism also occurs through the air, by

using PM10 as a carrier. In particular, it is shown that Piedmont cities, presenting lower detected infections cases in comparison to Brescia and Bergamo in the investigated period, had most sever PM10 pollution events in comparison to Lombardy cities. This first study may serve as a reference to better understand and predict the factors affecting the COVID-19 diffusion and transmission routes, focusing on the role of air particulate matter in the atmosphere.

Bontempi, E. "First data analysis about possible COVID-19 virus airborne diffusion due to air particulate matter (PM): the case of Lombardy (Italy)." Environmental Research (2020): 109639.

Short-Term Effects of Ambient Ozone, PM2.5, and Meteorological Factors on COVID-19 Confirmed Cases and Deaths in Queens, New York.

The outbreak of coronavirus disease 2019 (COVID-19), caused by the virus SARS-CoV-2, has been rapidly increasing in the United States. Boroughs of New York City, including Queens county, turn out to be the epicenters of this infection. According to the data provided by the New York State Department of Health, most of the cases of new COVID-19 infections in New York City have been found in the Queens county where 42,023 people have tested positive, and 3221 people have died as of 20 April 2020. Person-to-person transmission and travels were implicated in the initial spread of the outbreaks, but factors related to the late phase of rapidly spreading outbreaks in March and April are still uncertain. A few previous studies have explored the links between air pollution and COVID-19 infections, but more data is needed to understand the effects of short-term exposures of air pollutants and meteorological factors on the spread of COVID-19 infections, particularly in the U.S. disease epicenters. In this study, we have focused on ozone and PM2.5, two major air pollutants in New York City, which were previously found to be associated with respiratory viral infections. The aim of our regression modeling was to explore the associations among ozone, PM2.5, daily meteorological variables (wind speed, temperature, relative humidity, absolute humidity, cloud percentages, and precipitation levels), and COVID-19 confirmed new cases and new deaths in Queens county, New York during March and April 2020. The results from these analyses showed that daily average temperature, daily maximum eight-hour ozone concentration, average relative humidity, and cloud percentages were significantly and positively associated with new confirmed cases related to COVID-19; none of these variables showed significant associations with new deaths related to COVID-19. The findings indicate that short-term exposures to ozone and other meteorological factors can influence COVID-19 transmission and initiation of the disease, but disease aggravation and mortality depend on other factors.

Adhikari, Atin, and Jingjing Yin. "Short-Term Effects of Ambient Ozone, PM2. 5, and Meteorological Factors on COVID-19 Confirmed Cases and Deaths in Queens, New York." International Journal of Environmental Research and Public Health 17.11 (2020): 4047.

Air pollution and COVID-19: Is the connect worth its weight?

Primary route of transmission of SARS-CoV-2 among humans is droplets and direct contact. Airborne transmission of this virus is not established conclusively and so is the role of airborne particulate matter. This commentary examines the existing evidence about the role of particulate matter pollutants in SARS-CoV-2 transmission. PM2.5and other small particulate matter have been shown to carry viable virus particles in the air and incriminated in spread of measles and SARS coronavirus. Empirical evidence has been provided regarding role of air pollution in accelerated transmission of SARS-CoV-2 in Italy as well as Wuhan. Lockdown-related reduction in PM2.5levels in ambient air may have contributed to reduce transmission of SARS-CoV-2. High PM2.5levels in the past might have added to SARS-CoV-2 related mortality due to air pollution relate comorbidities. Post-lockdown increase in PM2.5levels may accelerate covid-19 transmission and can add to the burden of COVID-19 morbidity and mortality.

Sharma, Arun Kumar, and Palak Balyan. "Air pollution and COVID-19: Is the connect worth its weight?." Indian Journal of Public Health 64.6 (2020): 132.

Assessing the relationship between ground levels of ozone (O3) and nitrogen dioxide (NO2) with coronavirus (COVID-19) in Milan, Italy

This paper investigates the correlation between the high level of coronavirus SARS-CoV-2 infection accelerated transmission and lethality, and surface air pollution in Milan metropolitan area, Lombardy region in Italy. For January–April 2020 period, time series of daily average inhalable gaseous pollutants ozone (O3) and nitrogen dioxide (NO2), together climate variables (air temperature, relative humidity, wind speed, precipitation rate, atmospheric pressure field and Planetary Boundary Layer) were analyzed. In spite of being considered primarily transmitted by indoor bioaerosols droplets and infected surfaces or direct human-to-human personal contacts, it seems that high levels of urban air pollution, and climate conditions have a significant impact on SARS-CoV-2 diffusion. Exhibited positive correlations of ambient ozone levels and negative correlations of NO2 with the increased rates of COVID-19 infections (Total number, Daily New positive and Total Deaths cases), can be attributed to airborne bioaerosols distribution. The results show positive correlation of daily averaged O3 with air temperature and inversely correlations with relative humidity and precipitation rates. Viral genome contains distinctive features, including a unique N-terminal fragment within the spike protein, which allows coronavirus attachment on ambient air pollutants. At this moment it is not clear if through airborne diffusion, in the presence of outdoor and indoor aerosols, this protein “spike” of the new COVID-19 is involved in the infectious agent transmission from a reservoir to a susceptible host during the highest nosocomial outbreak in some agglomerated industrialized urban areas like Milan is. Also, in spite of collected data for cold season (winter-early spring) period, when usually ozone levels have lower values than in summer, the findings of this study support possibility as O3 can acts as a COVID-19 virus incubator. Being a novel pandemic coronavirus version, it might be ongoing during summer conditions associated with higher air temperatures, low relative humidity and precipitation levels.

Zoran, Maria A., et al. "Assessing the relationship between ground levels of ozone (O3) and nitrogen dioxide (NO2) with coronavirus (COVID-19) in Milan, Italy." Science of The Total Environment (2020): 140005.

Particulate Matter and COVID-19 Disease Diffusion in Emilia-Romagna (Italy). Already a Cold Case?

As we prepare to emerge from an extensive and unprecedented lockdown period, due to the COVID-19 virus infection that hit the Northern regions of Italy with the Europe’s highest death toll, it becomes clear that what has gone wrong rests upon a combination of demographic, healthcare, political, business, organizational, and climatic factors that are out of our scientific scope. Nonetheless, looking at this problem from a patient’s perspective, it is indisputable that risk factors, considered as associated with the development of the virus disease, include older age, history of smoking, hypertension and heart disease. While several studies have already shown that many of these diseases can also be favored by a protracted exposure to air pollution, there has been recently an insurgence of negative commentary against authors who have correlated the fatal consequences of COVID-19 (also) to the exposition of specific air pollutants. Well aware that understanding the real connection between the spread of this fatal virus and air pollutants would require many other investigations at a level appropriate to the scale of this phenomenon (e.g., biological, chemical, and physical), we propose the results of a study, where a series of the measures of the daily values of PM2.5, PM10, and NO2 were considered over time, while the Granger causality statistical hypothesis test was used for determining the presence of a possible correlation with the series of the new daily COVID19 infections, in the period February–April 2020, in Emilia-Romagna. Results taken both before and after the governmental lockdown decisions show a clear correlation, although strictly seen from a Granger causality perspective. Moving beyond the relevance of our results towards the real extent of such

a correlation, our scientific efforts aim at reinvigorating the debate on a relevant case, that should not remain unsolved or no longer investigated.

Delnevo, Giovanni, Silvia Mirri, and Marco Roccetti. "Particulate Matter and COVID-19 Disease Diffusion in Emilia-Romagna (Italy). Already a Cold Case?." Computation 8.2 (2020): 59.

Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic. A review

In recent years, a number of epidemiological studies have demonstrated that exposure to air pollution is associated with several adverse outcomes, such as acute lower respiratory infections, chronic obstructive pulmonary disease, asthma, cardiovascular diseases, and lung cancer among other serious diseases. Air pollutants such as sulfur oxides, nitrogen oxides, carbon monoxide and dioxide, particulate matter (PM), ozone and volatile organic compounds (VOCs) are commonly found at high levels in big cities and/or in the vicinity of different chemical industries. An association between air concentrations of these pollutants and human respiratory viruses interacting to adversely affect the respiratory system has been also reported. The present review was aimed at assessing the potential relationship between the concentrations of air pollutants on the airborne transmission of SARS-CoV-2 and the severity of COVID-19 in patients infected by this coronavirus. The results of most studies here reviewed suggest that chronic exposure to certain air pollutants leads to more severe and lethal forms of COVID-19 and delays/complicates the recovery of patients of this disease.

Domingo, José L., Montse Marquès, and Joaquim Rovira. "Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic. A review." Environmental Research (2020): 109861.

Air Pollution and Covid-19: The Role of Particulate Matter in the Spread and Increase of Covid-19's Morbidity and Mortality

Sars-cov-2 virus (Covid-19) is a member of the coronavirus family and is responsible for the pandemic recently declared by the World Health Organization. A positive correlation has been observed between the spread of the virus and air pollution, one of the greatest challenges of our millennium. Covid-19 could have an air transmission and atmospheric particulate matter (PM) could create a suitable environment for transporting the virus at greater distances than those considered for close contact. Moreover, PM induces inflammation in lung cells and exposure to PM could increase the susceptibility and severity of the Covid-19 patient symptoms. The new coronavirus has been shown to trigger an inflammatory storm that would be sustained in the case of pre-exposure to polluting agents. In this review, we highlight the potential role of PM in the spread of Covid-19, focusing on Italian cities whose PM daily concentrations were found to be higher than the annual average allowed during the months preceding the epidemic. Furthermore, we analyze the positive correlation between the virus spread, PM, and angiotensin-converting enzyme 2 (ACE2), a receptor involved in the entry of the virus into pulmonary cells and inflammation.

Comunian, Silvia, et al. "Air Pollution and Covid-19: The Role of Particulate Matter in the Spread and Increase of Covid-19's Morbidity and Mortality." International Journal of Environmental Research and Public Health 17.12 (2020): 4487.

Gaussian approach for probability and correlation between the number of COVID-19 cases and the air pollution in Lima

At the end of February 2020, Peru started the first cases of pneumonia associated with coronavirus (COVID-19), they were reported in Lima, Peru (Rodriguez-Morales et al., 2020). Therefore, the first week on March started with 72 infected people, the government published new law for a national crisis by COVID-19 pandemic (Vizcarra et al., 2020), with a quarantine in each city of Peru. Our analysis has considered

March and April 2020, for air quality measurement and infections in Lima, the data collected on 6 meteorological stations with CO (carbon monoxide), NO2 (nitrogen oxide), O3 (ozone), SO2 (sulfur dioxide), PM10 and PM2.5 (particle matter with diameter aerodynamic less than 2.5 and 10 m respectively). As a result, the average of these concentrations and the hospital information is recollected per hour. This analysis is executed during the quarantine an important correlation is discovered in the zone with highest infection by COVID-19, NO2 and PM10, even though in a reduction of air pollution in Lima. In this paper, we proposed a classification model by Reduced-Space Gaussian Process Regression for air pollution and infections; with technological and environmental dynamics and global change associated COVID-19. An evaluation of zones in Lima city, results have demonstrated influence of industrial influence in air pollution and infections by COVID-19 before and after quarantine during the last 28 days since the first infection in Peru; the problems relating to data management were validated with a successful classification and cluster analysis for future works in COVID-19 influence by environmental conditions.

Velásquez, Ricardo Manuel Arias, and Jennifer Vanessa Mejía Lara. "Gaussian approach for probability and correlation between the number of COVID-19 cases and the air pollution in Lima." Urban Climate (2020): 100664.

COVID-19 prevalence and fatality rates in association with air pollution emission concentrations and emission sources

The novel coronavirus disease (COVID-19) is primarily respiratory in nature, and as such, there is interest in examining whether air pollution might contribute to disease susceptibility or outcome. We merged data on COVID-19 cumulative prevalence and fatality rates as of May 31, 2020 with 2014–2019 pollution data from the US Environmental Protection Agency Environmental Justice Screen (EJSCREEN), with control for state testing rates, population density, and population covariate data from the County Health Rankings. Pollution data included three types of air emission concentrations (particulate matter<2.5 μm (PM2.5), ozone and diesel particulate matter (DPM)), and four pollution source variables (proximity to traffic, National Priority List sites, Risk Management Plan (RMP) sites, and hazardous waste treatment, storage and disposal facilities (TSDFs)). Results of mixed model linear multiple regression analyses indicated that, controlling for covariates, COVID-19 prevalence and fatality rates were significantly associated with greater DPM. Proximity to TSDFs was associated to greater fatality rates, and proximity to RMPs was associated with greater prevalence rates. Results are consistent with previous research indicating that air pollution increases susceptibility to respiratory viral pathogens. Results should be interpreted cautiously given the ecological design, the time lag between exposure and outcome, and the uncertainties in measuring COVID-19 prevalence. Areas with worse prior air quality, especially higher concentrations of diesel exhaust, may be at greater COVID-19 risk, although further studies are needed to confirm these relationships.

Hendryx, Michael, and Juhua Luo. "COVID-19 prevalence and fatality rates in association with air pollution emission concentrations and emission sources." Environmental Pollution (2020): 115126.

Ambient Air Pollution, Meteorology, and COVID‐19 Infection in Korea

The outbreak of novel pneumonia coronavirus disease has become a public health concern worldwide. Here, for the first time, the association between Korean meteorological factors and air pollutants and the COVID‐19 infection was investigated. Data of air pollutants, meteorological factors, and daily COVID‐19 confirmed cases of 7 metropolitan cities and 9 provinces were obtained from February 03, 2020 to May 05, 2020 during the first wave of pandemic across Korea. We applied the generalized additive model to investigate the temporal relationship. There was a significantly non‐linear association between daily temperature and COVID‐19 confirmed cases. Each 1oC increase in temperature was associated with 9% (lag 0‐14, OR=1.09, 95% CI=1.03‐1.15) increase of COVID‐19 confirmed cases when the temperature was below 8oC. A 0.01 ppm increase in NO2 (lag 0‐7, lag 0.14, and lag 0‐21) was significantly associated

with increases of COVID‐19 confirmed cases, with ORs (95% CIs) of 1.13 (1.02‐1.25), 1.19 (1.09‐1.30), and 1.30 (1.19‐1.41), respectively. A 0.1 ppm increase in CO (lag 0‐21) was associated with the increase in COVID‐19 confirmed cases (OR=1.10, 95% CI=1.04‐1.16). There was a positive association between per 0.001 ppm of SO2 concentration (lag 0, lag 0‐7, and lag 0‐14) and COVID‐19 confirmed cases, with ORs (95% CIs) of 1.13 (1.04‐1.22), 1.20 (1.11‐1.31), and 1.15 (1.07‐1.25), respectively. There were significantly temporal associations between temperature, NO2, CO, and SO2 concentrations and daily COVID‐19 confirmed cases in Korea.

Hoang, Tung, and Tho Tran Thi Anh. "Ambient Air Pollution, Meteorology, and COVID‐19 Infection in Korea." Journal of Medical Virology.

Spread of SARS-CoV-2 through Latin America and the Caribbean region: a look from its economic conditions, climate and air pollution indicators

We have evaluated the spread of SARS-CoV-2 through Latin America and the Caribbean (LAC) region by means of a correlation between climate and air pollution indicators, namely, average temperature, minimum temperature, maximum temperature, rainfall, average relative humidity, wind speed, and air pollution indicators PM10, PM2.5, and NO2 with the COVID-19 daily new cases and deaths. The study focuses in the following LAC cities: Mexico City (Mexico), Santo Domingo (Dominican Republic), San Juan (Puerto Rico), Bogotá (Colombia), Guayaquil (Ecuador), Manaus (Brazil), Lima (Perú), Santiago (Chile), São Paulo (Brazil) and Buenos Aires (Argentina). The results show that average temperature, minimum temperature, and air quality were significantly associated with the spread of COVID-19 in LAC. Additionally, humidity, wind speed and rainfall showed a significant relationship with daily cases, total cases and mortality for various cities. Income inequality and poverty levels were also considered as a variable for qualitative analysis. Our findings suggest that and income inequality and poverty levels in the cities analyzed were related to the spread of COVID-19 positive and negative, respectively. These results might help decision-makers to design future strategies to tackle the spread of COVID-19 in LAC and around the world.

Bolaño-Ortiz, Tomás R., et al. "Spread of SARS-CoV-2 through Latin America and the Caribbean region: a look from its economic conditions, climate and air pollution indicators." Environmental Research (2020): 109938.

Influence of the Covid-19 Crisis on Global PM2.5 Concentration and Related Health Impacts

The decrease in human activities following the COVID-19 pandemic caused an important change in PM2.5 concentration, especially in the most polluted areas in the world: China (44.28 and 18.88 µg/m3 in the first quarters of 2019 and 2020, respectively), India (49.84 and 31.12, respectively), and Nigeria (75.30 and 34.31, respectively). In this study, satellite observations from all around the world of PM2.5 concentration were collected on the grid scale with a high resolution of 0.125° (about 15km). Population data for 2020 were also collected on the same scale. Statistical data from the World Health Organization (WHO) concerning the diseases caused by air pollution (e.g., stroke) were obtained for each country to determine the change in mortality between the first quarter of 2019 and the first quarter of 2020. Expressed in disability-adjusted life years (DALY), it was found that the largest reductions were observed for China (-13.9 million DALY), India (-6.3 million DALY), and Nigeria (-2.3 million DALY).

Karkour, Selim, and Norihiro Itsubo. "Influence of the Covid-19 Crisis on Global PM2. 5 Concentration and Related Health Impacts." Sustainability 12.13 (2020): 5297.

Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States

To date, COVID-19 has claimed more than 100 000 American lives. Early inquiry suggests preexisting conditions are key risk factors contributing to COVID-19 mortality and air pollution exposure could exacerbate this relationship. Building on prior research linking deaths from respiratory viruses to air pollution exposures, we investigate how 2014 National Air Toxics Assessment hazardous air pollutants (HAPs) respiratory hazard quotient and respiratory hazard index are related to COVID-19 mortality. Our focus on HAPs builds upon the knowledge base linking poor air quality to COVID-19 mortality, since most (if not all) earlier studies only include criteria pollutants. Herein, we examine the relationship between HAP exposure and US-based COVID-19 mortality, while controlling for socioeconomic status, population health indicators, and exposure to PM2.5 and ozone. We fit county-level negative binomial mixed models, predicting COVID-19 mortality as a function of HAP respiratory toxicity levels and relevant covariates. We include models for combined exposure to HAPs, as well as for specific pollutants. We find that an increase in the respiratory hazard index is associated with a 9% increase in COVID-19 mortality. Although differing in magnitude, this association holds for individual HAPs acetaldehyde, and diesel PM. These findings help us to understand variation in US-based COVID-19 mortality rates, reinforce existing research linking air pollution to mortality, and emphasize the importance of regulatory efforts to limit air pollution exposure risk.

Petroni, Michael, et al. "Hazardous air pollutant exposure as a contributing factor to COVID-19 mortality in the United States." Environmental Research Letters 15.9 (2020): 0940a9.

Chronic exposure to air pollution implications on COVID-19 severity

Populations in areas with higher levels of air pollution both indoors and outdoors show increased mortality rates when infected with coronavirus disease 2019 (COVID-19). The association between air quality and COVID-19 is commonly attributed to the risk of transmission. Although controlled transmission is crucial, further investigation into air quality traits that contribute to the lethality of COVID-19 in infected persons enables risk stratification and optimization of the allocation of resources. There is a need for a valid basis for the proactive identification of indicators of COVID-19 severity in air quality that allow for the implementation of systematic environmental improvements aimed at preventing COVID-19 mortality. In this paper, chronic exposure to fine particulate matter (PM) is identified as a source of disrupted activation of the hypothalamic–pituitary–adrenal (HPA) axis; it is therefore, a contributable variable to COVID-19 mortality.

Deek, Sarah A. "Chronic Exposure to Air Pollution Implications on COVID-19 Severity." Medical Hypotheses (2020): 110303.

Short-term and long-term health impacts of air pollution reductions from COVID-19 lockdowns in China and Europe: a modelling study

Exposure to poor air quality leads to increased premature mortality from cardiovascular and respiratory diseases. Among the far-reaching implications of the ongoing COVID-19 pandemic, a substantial improvement in air quality was observed worldwide after the lockdowns imposed by many countries. We aimed to assess the implications of different lockdown measures on air pollution levels in Europe and China, as well as the short-term and long-term health impact. For this modelling study, observations of fine particulate matter (PM2·5) concentrations from more than 2500 stations in Europe and China during 2016–20 were integrated with chemical transport model simulations to reconstruct PM2·5 fields at high spatiotemporal resolution. The health benefits, expressed as short-term and long-term avoided mortality from PM2·5 exposure associated with the interventions imposed to control the COVID-19 pandemic, were quantified on the basis of the latest epidemiological studies. To explore the long-term variability in air quality and associated premature mortality, we built different scenarios of economic recovery (immediate

or gradual resumption of activities, a second outbreak in autumn, and permanent lockdown for the whole of 2020). The lockdown interventions led to a reduction in population-weighted PM2·5 of 14·5 μg m-3 across China (-29·7%) and 2·2 μg m-3 across Europe (-17·1%), with unprecedented reductions of 40 μg m-3 in bimonthly mean PM2·5 in the areas most affected by COVID-19 in China. In the short term, an estimated 24 200 (95% CI 22 380–26 010) premature deaths were averted throughout China between Feb 1 and March 31, and an estimated 2190 (1960–2420) deaths were averted in Europe between Feb 21 and May 17. We also estimated a positive number of long-term avoided premature fatalities due to reduced PM2·5 concentrations, ranging from 76 400 (95% CI 62 600–86 900) to 287 000 (233 700–328 300) for China, and from 13 600 (11 900–15 300) to 29 500 (25 800–33 300) for Europe, depending on the future scenarios of economic recovery adopted. These results indicate that lockdown interventions led to substantial reductions in PM2·5 concentrations in China and Europe. We estimated that tens of thousands of premature deaths from air pollution were avoided, although with significant differences observed in Europe and China. Our findings suggest that considerable improvements in air quality are achievable in both China and Europe when stringent emission control policies are adopted

Giani, Paolo, et al. "Short-term and long-term health impacts of air pollution reductions from COVID-19 lockdowns in China and Europe: a modelling study." The Lancet Planetary Health (2020).

Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States

The novel human coronavirus disease 2019 (COVID-19) pandemic has claimed more than 240,000 lives worldwide, causing tremendous public health, social, and economic damages. While the risk factors of COVID-19 are still under investigation, environmental factors, such as urban air pollution, may play an important role in increasing population susceptibility to COVID-19 pathogenesis. We conducted a cross-sectional nationwide study using zero-inflated negative binomial models to estimate the association between long-term (2010–2016) county-level exposures to NO2, PM2.5 and O3 and county-level COVID-19 case-fatality and mortality rates in the US. We used both single and multipollutant models and controlled for spatial trends and a comprehensive set of potential confounders, including state-level test positive rate, county-level healthcare capacity, phase-of-epidemic, population mobility, sociodemographic, socioeconomic status, behavior risk factors, and meteorological factors. 1,027,799 COVID-19 cases and 58,489 deaths were reported in 3,122 US counties from January 22, 2020 to April 29, 2020, with an overall observed case-fatality rate of 5.8%. Spatial variations were observed for both COVID-19 death outcomes and long-term ambient air pollutant levels. County-level average NO2 concentrations were positively associated with both COVID-19 case-fatality rate and mortality rate in single-, bi-, and tri-pollutant models (p-values<0.05). Per inter-quartile range (IQR) increase in NO2 (4.6 ppb), COVID-19 case-fatality rate and mortality rate were associated with an increase of 7.1% (95% CI 1.2% to 13.4%) and 11.2% (95% CI 3.4% to 19.5%), respectively. We did not observe significant associations between long-term exposures to PM2.5 or O3 and COVID-19 death outcomes (p-values>0.05), although per IQR increase in PM2.5 (3.4 ug/m3) was marginally associated with 10.8% (95% CI: -1.1% to 24.1%) increase in COVID-19 mortality rate. Long-term exposure to NO2, which largely arises from urban combustion sources such as traffic, may enhance susceptibility to severe COVID-19 outcomes, independent of long-term PM2.5 and O3 exposure. The results support targeted public health actions to protect residents from COVID-19 in heavily polluted regions with historically high NO2 levels. Moreover, continuation of current efforts to lower traffic emissions and ambient air pollution levels may be an important component of reducing population-level risk of COVID-19 deaths.

Liang, Donghai, et al. "Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States." medRxiv (2020).

The relationship between air pollution and COVID-19-related deaths: An application to three French cities

Being heavily dependent to oil products (mainly gasoline and diesel), the French transport sector is the main emitter of Particulate Matter (PMs) whose critical levels induce harmful health effects for urban inhabitants. We selected three major French cities (Paris, Lyon, and Marseille) to investigate the relationship between the Coronavirus Disease 19 (COVID-19) outbreak and air pollution. Using Artificial Neural Networks (ANNs) experiments, we have determined the concentration of PM2.5 and PM10 linked to COVID-19-related deaths. Our focus is on the potential effects of Particulate Matter (PM) in spreading the epidemic. The underlying hypothesis is that a pre-determined particulate concentration can foster COVID-19 and make the respiratory system more susceptible to this infection. The empirical strategy used an innovative Machine Learning (ML) methodology. In particular, through the so-called cutting technique in ANNs, we found new threshold levels of PM2.5 and PM10 connected to COVID-19: 17.4 µg/m3 (PM2.5) and 29.6 µg/m3 (PM10) for Paris; 15.6 µg/m3 (PM2.5) and 20.6 µg/m3 (PM10) for Lyon; 14.3 µg/m3 (PM2.5) and 22.04 µg/m3 (PM10) for Marseille. Interestingly, all the threshold values identified by the ANNs are higher than the limits imposed by the European Parliament. Finally, a Causal Direction from Dependency (D2C) algorithm is applied to check the consistency of our findings.

Magazzino, Cosimo, Marco Mele, and Nicolas Schneider. "The relationship between air pollution and COVID-19-related deaths: an application to three French cities." Applied Energy (2020): 115835.

The role of air pollution (PM and NO2) in COVID-19 spread and lethality: A systematic review

A new coronavirus (SARS-CoV-2) has determined a pneumonia outbreak in China (Wuhan, Hubei Province) in December 2019, called COVID-19 disease. In addition to the person-to person transmission dynamic of the novel respiratory virus, it has been recently studied the role of environmental factors in accelerate SARS-CoV-2 spread and its lethality. The time being, air pollution has been identified as the largest environmental cause of disease and premature death in the world. It affects body's immunity, making people more vulnerable to pathogens. The hypothesis that air pollution, resulting from a combination of factors such as meteorological data, level of industrialization as well as regional topography, can acts both as a carrier of the infection and as a worsening factor of the health impact of COVID-19 disease, has been raised recently. With this review, we want to provide an update state of art relating the role of air pollution, in particular PM2.5, PM10 and NO2, in COVID-19 spread and lethality. The Authors, who first investigated this association, often used different research methods or not all include confounding factors whenever possible. In addition, to date incidence data are underestimated in all countries and to a lesser extent also mortality data. For this reason, the cases included in the reviewed studies cannot be considered conclusive. Although it determines important limitations for direct comparison of results, and more studies are needed to strengthen scientific evidences and support firm conclusions, major findings are consistent, highlighting the important contribution of PM2.5 and NO2 as triggering of the COVID-19 spread and lethality, and with a less extent also PM10, although the potential effect of airborne virus exposure it has not been still demonstrated.

Copat, Chiara, et al. "The role of air pollution (PM and NO2) in COVID-19 spread and lethality: A systematic review." Environmental Research (2020): 110129.

Air Pollution Exposure and Covid-19 in Dutch Municipalities

In light of the existing preliminary evidence of a link between Covid-19 and poor air quality, which is largely based upon correlations, we estimate the relationship between long term air pollution exposure and Covid-19 in 355 municipalities in the Netherlands. Using detailed data we find compelling evidence of a positive relationship between air pollution, and particularly PM2.5 concentrations, and Covid-19 cases,

hospital admissions and deaths. This relationship persists even after controlling for a wide range of explanatory variables. Our results indicate that, other things being equal, a municipality with 1 µg/m3 more PM2.5 concentrations will have 9.4 more Covid-19 cases, 3.0 more hospital admissions, and 2.3 more deaths. This relationship between Covid-19 and air pollution withstands a number of sensitivity and robustness exercises including instrumenting pollution to mitigate potential endogeneity in the measurement of pollution and modelling spatial spillovers using spatial econometric techniques.

Cole, Matthew A., Ceren Ozgen, and Eric Strobl. "Air Pollution Exposure and Covid-19 in Dutch Municipalities." Environmental and Resource Economics 76.4 (2020): 581-610.

Links between air pollution and COVID-19 in England

In December 2019, a novel disease, coronavirus disease 19 (COVID-19), emerged in Wuhan, People's Republic of China. COVID-19 is caused by a novel coronavirus (SARS-CoV-2) presumed to have jumped species from another mammal to humans. This virus has caused a rapidly spreading global pandemic. To date, over 300,000 cases of COVID-19 have been reported in England and over 40,000 patients have died. While progress has been achieved in managing this disease, the factors in addition to age that affect the severity and mortality of COVID-19 have not been clearly identified. Recent studies of COVID-19 in several countries identified links between air pollution and death rates. Here, we explored potential links between major fossil fuel-related air pollutants and SARS-CoV-2 mortality in England. We compared current SARS-CoV-2 cases and deaths from public databases to both regional and subregional air pollution data monitored at multiple sites across England. After controlling for population density, age and median income, we show positive relationships between air pollutant concentrations, particularly nitrogen oxides, and COVID-19 mortality and infectivity. Using detailed UK Biobank data, we further show that PM2.5 was a major contributor to COVID-19 cases in England, as an increase of 1 m3 in the long-term average of PM2.5 was associated with a 12% increase in COVID-19 cases. The relationship between air pollution and COVID-19 withstands variations in the temporal scale of assessments (single-year vs 5-year average) and remains significant after adjusting for socioeconomic, demographic and health-related variables. We conclude that a small increase in air pollution leads to a large increase in the COVID-19 infectivity and mortality rate in England. This study provides a framework to guide both health and emissions policies in countries affected by this pandemic.

Travaglio, Marco, et al. "Links between air pollution and COVID-19 in England." medRxiv (2020).

Monitoring the Impact of Air Quality on the COVID-19 Fatalities in Delhi, India: Using Machine Learning Techniques

The focus of this study is to monitor the effect of lockdown on the various air pollutants due to COVID-19 pandemic and identify the ones that affect COVID-19 fatalities so that measures to control the pollution could be enforced. Various machine learning techniques: Decision Trees, Linear Regression and Random Forest have been applied to correlate air pollutants and COVID-19 fatalities in Delhi. Furthermore, a comparison between the concentration of various air pollutants and the air quality index during lockdown period and last two years 2018 and 2019 has been presented. From the experimental work, it has been observed that the pollutants Ozone and Toluene have increased during the lockdown period. It has also been deduced that the pollutants that may impact the mortalities due to COVID-19 are Ozone, NH3, NO2, and PM10. The novel corona virus has led to environmental restoration due to lockdown. However, there is a need to impose measures to control Ozone pollution as there has been a significant increase in its concentration and it also impacts the COVID-19 mortality rate.

Sethi, Jasleen Kaur, and Mamta Mittal. "Monitoring the Impact of Air Quality on the COVID-19 Fatalities in Delhi, India: Using Machine Learning Techniques." Disaster Medicine and Public Health Preparedness: 1-17.

Effects of air pollution on the potential transmission and mortality of COVID-19: A preliminary case-study in Tarragona Province (Catalonia, Spain)

The number of studies published on COVID-19 in recent months is certainly impressive. However, there are still important gaps to know a great number of characteristics of this disease. Among these, some potential ways of transmission of the SARS-CoV-2 and the different reasons for the severity of the disease in different people. Various studies have suggested that certain air pollutants could be increasing the transmission of the coronavirus, as well as the risks of COVID-19 incidence and mortality. In the present preliminary case-study conducted in Tarragona Province (Catalonia, Spain), we studied the potential association of COVID-19 with PM10, NO2 and O3, as well as the differences in the incidence and lethality of this disease. This Province is divided into two "health regions": Camp de Tarragona, with an important industrial complex, and Terres de l'Ebre, with a great agricultural component. In spite of the notable limitations of the current study, our preliminary findings indicate that the industrialized/urban areas of Tarragona Province show a higher incidence and mortality of COVID-19 than the agricultural/rural zones. These – and previous – results would highlight the importance of conducting specific investigations focused on directly assessing whether air pollutants such as particulate matter can act as carriers of the SARS-CoV-2. If confirmed, the recommendation on keeping the "social distance" (1.5–2 m) might need to be adapted to this situation.

Marquès, Montse, et al. "Effects of air pollution on the potential transmission and mortality of COVID-19: A preliminary case-study in Tarragona Province (Catalonia, Spain)." Environmental Research (2020): 110315.

Regional and global contributions of air pollution to risk of death from COVID-19

The risk of mortality from the coronavirus disease that emerged in 2019 (COVID-19) is increased by comorbidity from cardiovascular and pulmonary diseases. Air pollution also causes excess mortality from these conditions. Analysis of the first severe acute respiratory syndrome coronavirus (SARS-CoV-1) outcomes in 2003, and preliminary investigations of those for SARS-CoV-2 since 2019, provide evidence that the incidence and severity are related to ambient air pollution. We estimated the fraction of COVID-19 mortality that is attributable to the long-term exposure to ambient fine particulate air pollution. We characterized global exposure to fine particulates based on satellite data, and calculated the anthropogenic fraction with an atmospheric chemistry model. The degree to which air pollution influences COVID-19 mortality was derived from epidemiological data in the USA and China. We estimate that particulate air pollution contributed ~15% (95% confidence interval 7–33%) to COVID-19 mortality worldwide, 27% (13 – 46%) in East Asia, 19% (8–41%) in Europe, and 17% (6–39%) in North America. Globally, ~50–60% of the attributable, anthropogenic fraction is related to fossil fuel use, up to 70–80% in Europe, West Asia, and North America. Our results suggest that air pollution is an important cofactor increasing the risk of mortality from COVID-19. This provides extra motivation for combining ambitious policies to reduce air pollution with measures to control the transmission of COVID-19.

Pozzer, Andrea, et al. "Regional and global contributions of air pollution to risk of death from COVID-19." Cardiovascular Research (2020).

Air pollution declines during COVID-19 lockdowns mitigate the global health burden

The lockdown response to COVID-19 has resulted in an unprecedented reduction in global economic activity and associated air pollutant levels, especially from a decline in land transportation. We utilized a network of >10,000 air quality stations distributed over 34 countries during lockdown dates up until 15 May 2020 to obtain lockdown related anomalies for nitrogen dioxide, ozone and particulate matter smaller than 2.5 µm in diameter (PM2.5). Pollutant anomalies were related to short-term health outcomes using

empirical exposure-response functions. We estimate that there were a net total of 49,900 (11,000 to 90,000; 95% confidence interval) excess deaths and 89,000 (64,700 to 107,000) pediatric asthma emergency room visits avoided during lockdowns. In China and India alone, the PM2.5-related avoided excess mortality was 19,600 (15,300 to 24,000) and 30,500 (5700 to 68,000), respectively. While the state of COVID-19 imposed lockdown is not sustainable, these findings illustrate the potential health benefits gained by reducing "business as usual" air pollutant emissions from economic activities primarily through finding alternative transportation solutions.

Kutralam-Muniasamy, Gurusamy, et al. "Impacts of the COVID-19 lockdown on air quality and its association with human mortality trends in megapolis Mexico City." Air Quality, Atmosphere & Health (2020): 1-10.

Population-weighted exposure to air pollution and COVID-19 incidence in Germany

Many countries have enforced social distancing to stop the spread of COVID-19. Within countries, although the measures taken by governments are similar, the incidence rate varies among areas (e.g., counties, cities). One potential explanation is that people in some areas are more vulnerable to the coronavirus disease because of their worsened health conditions caused by long-term exposure to poor air quality. In this study, we investigate whether long-term exposure to air pollution increases the risk of COVID-19 infection in Germany. The results show that nitrogen dioxide (NO_2) is significantly associated with COVID-19 incidence, with a 1 ug m^{-3} increase in long-term exposure to NO_2 increasing the COVID-19 incidence rate by 5.58% (95% credible interval [CI]: 3.35%, 7.86%). This result is consistent across various models. The analyses can be reproduced and updated routinely using public data sources and shared R code.

Huang, Guowen, and Patrick E. Brown. "Population-weighted exposure to air pollution and COVID-19 incidence in Germany." Spatial Statistics (2020): 100480.

Expected Health Effects of Reduced Air Pollution from COVID-19 Social Distancing

The COVID-19 pandemic resulted in stay-at-home policies and other social distancing behaviors in the United States in spring of 2020. This paper examines the impact that these actions had on emissions and expected health effects through reduced personal vehicle travel and electricity consumption. Using daily cell phone mobility data for each U.S. county, we find that vehicle travel dropped about 40% by mid-April across the nation. States that imposed stay-at-home policies before March 28 decreased travel slightly more than other states, but travel in all states decreased significantly. Using data on hourly electricity consumption by electricity region (e.g., balancing authority), we find that electricity consumption fell about six percent on average by mid-April with substantial heterogeneity. Given these decreases in travel and electricity use, we estimate the county-level expected improvements in air quality, and therefore expected declines in mortality. Overall, we estimate that, for a month of social distancing, the expected premature deaths due to air pollution from personal vehicle travel and electricity consumption declined by approximately 360 deaths, or about 25% of the baseline 1500 deaths. In addition, we estimate that CO2 emissions from these sources fell by 46 million metric tons (a reduction of approximately 19%) over the same time frame.

Cicala, Steve, et al. Expected Health Effects of Reduced Air Pollution from COVID-19 Social Distancing. No. w27135. National Bureau of Economic Research, 2020.

Associations between mortality from COVID-19 in two Italian regions and outdoor air pollution as assessed through tropospheric nitrogen dioxide

After the appearance of COVID-19 in China last December 2019, Italy was the first European country to be severely affected by the outbreak. The first diagnosis in Italy was on February 20, 2020, followed by the

establishment of a light and a tight lockdown on February 23 and on March 8, 2020, respectively. The virus spread rapidly, particularly in the North of the country in the 'Padan Plain' area, known as one of the most polluted regions in Europe. Air pollution has been recently hypothesized to enhance the clinical severity of SARS-CoV-2 infection, acting through adverse effects on immunity, induction of respiratory and other chronic disease, upregulation of viral receptor ACE-2, and possible pathogen transportation as a virus carrier. We investigated the association between air pollution and subsequent COVID-19 mortality rates within two Italian regions (Veneto and Emilia-Romagna). We estimated ground-level nitrogen dioxide through its tropospheric levels using data available from the Sentinel-5P satellites of the European Space Agency Copernicus Earth Observation Programme before the lockdown. We then examined COVID-19 mortality rates in relation to the nitrogen dioxide levels at three 14-day lag points after the lockdown, namely March 8, 22 and April 5, 2020. Using a multivariable negative binomial regression model, we found an association between nitrogen dioxide and COVID-19 mortality. Although ecological data provide only weak evidence, these findings indicate an association between air pollution levels and COVID-19 severity.

Filippini, Tommaso, et al. "Associations between mortality from COVID-19 in two Italian regions and outdoor air pollution as assessed through tropospheric nitrogen dioxide." Science of The Total Environment (2020): 143355.

SOCIO-ECONOMIC IMPCATS, CLIMATE IMPCATS AND OTHER RELEVANT TOPICS ABOUT COVID-19, AND POLICE IMPLICATION

Navigating the Clean Energy Transition in the COVID-19 Crisis

Conclusion: What does the COVID-19 crisis imply for the energy transition required to keep global warming at bay? Many commentators and advocates have been quick to provide answers and ready-made solutions. We take a step back and pursue a different approach. In our view, structuring the challenges that arise in different time horizons and offering guiding principles for responses are most useful at this stage. We recommend three principles: (1) avoid overreacting in the short term. (2) Make use of new opportunities for the energy transition in the mid-term. (3) Develop new policy designs that can withstand future shocks. While now the policy attention is rightfully focused on the public health crisis and mitigating its immediate effects, it is important to navigate the new situation without jeopardizing the imperative clean energy transition.

Steffen, Bjarne, et al. "Navigating the Clean Energy Transition in the COVID-19 Crisis." Joule (2020).

Valuation of air pollution externalities: comparative assessment of economic damage and emission reduction under COVID-19 lockdown

Air pollution (AP) is one of the major causes of health risks as it leads to widespread morbidity and mortality each year. Its environmental impacts include acid rains, reduced visibility, but more importantly and significantly, it affects human health. The price tag of not managing AP is seen in the rise of chronic obstructive pulmonary disease (COPD), cardiovascular disease, and respiratory ailments like asthma and chronic bronchitis. But as the world battles the corona pandemic, COVID-19 lockdown has abruptly halted human activity, leading to a significant reduction in AP levels. The effect of this reduction is captured by reduced cases of morbidity and mortality associated with air pollution. The current study aims to monetarily quantify the decline in health impacts due to reduced AP levels under lockdown scenario, as against business as usual, for four cities—Delhi, London, Paris, and Wuhan. The exposure assessment with respect to pollutants like particulate matter (PM2.5 and PM10), NO2, and SO2 are evaluated. Value of statistical life (VSL), cost of illness (CoI), and per capita income (PCI) for disability-adjusted life years (DALY) are used to monetize the health impacts for the year 2019 and 2020, considering the respective period of

COVID-19 lockdown of four cities. The preventive benefits related to reduced AP due to lockdown is evaluated in comparison to economic damage sustained by these four cities. This helps in understanding the magnitude of actual damage and brings out a more holistic picture of the damages related to lockdown.

Bherwani, H., Nair, M., Musugu, K. et al. Valuation of air pollution externalities: comparative assessment of economic damage and emission reduction under COVID-19 lockdown. Air Qual Atmos Health (2020). https://doi.org/10.1007/s11869-020-00845-3

Global assessment of environment, health and economic impact of the novel coronavirus (COVID-19)

The institution of social distancing and punitive measures to contain the spread of COVID-19 through human-to-human transmission has environmental, health and economic impact. While the global pandemic has led to the enhancement of the health system and decline of emissions, economic development appears deteriorating. Here, we present the global environmental, health and economic dimension of the effect of COVID-19 using qualitative and empirical assessments. We report the health system policies, environmental sustainability issues, and fiscal, monetary and exchange rate measures introduced during lockdown across countries. While air pollution is reported to have declined, municipal and medical waste is increasing. The COVID-19 global pandemic uncertainty ranks the UK as the country with the highest uncertainty level among 143 countries. The USA has introduced 100% of pre-COVID-19 crisis level GDP, the highest policy cut-rate among 162 countries. Science, innovation, research and development underpin COVID-19 containment measures implemented across countries. Our study demonstrates the need for future research to focus on environment-health-economic nexus—a trilemma that has a potential trade-off.

Sarkodie, Samuel Asumadu, and Phebe Asantewaa Owusu. "Global assessment of environment, health and economic impact of the novel coronavirus (COVID-19)." Environment, Development and Sustainability (2020): 1-11.

The dramatic impact of Coronavirus outbreak on air quality: Has it saved as much as it has killed so far?

The outbreak of coronavirus disease (COVID-19) was first reported from Wuhan, China, on December 31st, 2019. As the number of coronavirus infections has exceeded 100,000 with toll deaths of about 5000 worldwide as of early March, 2020, scientists and researchers are racing to investigate the nature of this virus and evaluate the short and long term effects of this disease. Despite its negative impacts that obliged the World Health Organization to declare COVID-19 epidemic as a Public Health Emergency of International Concern, the rate of mortality of this infection has not exceeded 3.4% globally. On the other hand, the mortality rate caused by ambient air pollution has contributed to 7.6% of all deaths in 2016 worldwide. The outbreak of COVID-19 has forced China to lockdown its industrial activities and hence dropped its NO_2 and carbon emissions by 30 and 25%, respectively. This work reports on the first case study that compares the air quality status before and after the crisis. It sheds light on the facts related to the demographics of deaths by gender, age and health status before infection. The historical data on air quality, estimates of annual deaths and its economic burden have been presented and analyzed. The actual daily deaths due to COVID-19 have been obtained from the official records of the daily Situation Reports published by World Health Organization as of March 11th. The rate of mortality due to COVID-19 was impacted by two factors: age and health status. Results show that 75% of deaths were related to cases that had underlying present diseases with the majority aged of 80+ years. The reported figures were compared with the average daily mortality due to poor air quality which reached up to 3287 deaths due to high levels of NO_2, O_3 and PM.

The air quality status before the crisis was compared with the current situation showing that COVID-19 forced-industrial and anthropogenic activities lockdown may have saved more lives by preventing ambient air pollution than by preventing infection.

Isaifan, R. J. "The dramatic impact of Coronavirus outbreak on air quality: Has it saved as much as it has killed so far?." Global Journal of Environmental Science and Management 6.3 (2020): 275-288.

Environmental impact of the COVID-19 pandemic – a lesson for the future

The environment is an integral component of human and animal health. COVID-19 is a global health challenge in the twenty-first century. The emergence of SARS-CoV-2 in Wuhan, China in December 2019, and its spread to regional countries and nowadays affecting more than 210 countries worldwide represents the first pandemic in history to be caused by a coronavirus. The COVID-19 pandemic has huge impacts on most aspects of human activities, as well as on the economy and health care systems. Lock-downs, quarantines and border closures in the wake of the pandemic have led to reductions in air pollution through decreased travel and production. These positive environmental effects are likely mostly temporary, but may serve as an example that changes in our way of life can have prompt positive effects for the environment and demonstrate the usefulness of travel-reducing measures such as teleconferencing. Thus, acknowledging that COVID-19 is first and foremost a global disaster, the pandemic may inspire to future behavioral changes with positive environmental effects.

El Zowalaty, Mohamed E., Sean G. Young, and Josef D. Järhult. "Environmental impact of the COVID-19 pandemic–a lesson for the future." (2020): 1768023.

Changes in Sustainability Priorities in Organisations due to the COVID-19 Outbreak: Averting Environmental Rebound Effects on Society

The COVID-19 outbreak has affected societies and organisations in an unprecedented way. This has resulted in negative impacts to economic and social issues, but it is a “blessing in disguise” for environmental issues. This paper analyses how the outbreak has affected organisations’ sustainability priorities. Prior to the COVID-19 outbreak, such priorities were on the economic dimension followed by the environmental and social dimensions. A survey was sent to 11,657 organisations to analyse such changes, with a 5.60% response rate. The results show that for organisations, the main priority is now on the social dimension, followed by the economic one; however, the environmental dimension has suffered a negative impact in prioritisation, regardless of organisation type, country where they are based, organisation size, or the time they have been working on sustainability. We are currently facing an environmental conundrum, where air quality has improved and pollution has decreased in societies, but organisations are starting to neglect such environmental issues. The COVID-19 outbreak is an opportunity for organisations to better contribute to sustainability by ensuring that the efforts that have been undertaken in the last three decades are not forgotten, and that societies and organisations are better coupled to face such crises and avert rebound effects.

Barreiro-Gen, Maria, Rodrigo Lozano, and Afnan Zafar. "Changes in Sustainability Priorities in Organisations due to the COVID-19 Outbreak: Averting Environmental Rebound Effects on Society." Sustainability 12.12 (2020): 5031.

Covid-19 and air pollution: communicating the results of geographic correlation studies

The Covid-19 pandemic has conveyed a great deal of interest in epidemiology, which has received unprecedented attention within the scientific community, as well as from the media and from decision makers. Some of the many scientific articles regarding the SARS-CoV-2 outbreak published or released in pre-print mode examined the relationship between air pollution and Covid-19 cases or deaths. They

received ample media coverage, attracted public attention, and raised a debate that will presumably continue. The community of environmental epidemiologists was positively surprised by this remarkable interest, but some concerns arose from the interpretations of the results, which were not consistent with the study design. This text intends to propose some reflections regarding the messages emerged from a limited number of epidemiological studies, chosen as an example to underline the reasons for the great interest and the wide media coverage.

Cori, Liliana, and Fabrizio Bianchi. "Covid-19 and air pollution: communicating the results of geographic correlation studies." Epidemiol Prev 44.2-3 (2020): 120-123.

Take advantage of the black swan to improve the urban environment

The outbreak of the COVID-19 virus for all humanity is a typical example of the birth of the black swan, a metaphor that indicates the event of very low probability, therefore unpredictable and a source of crisis. Statistics and probability theory teach that any deterministic hypothesis of forecasting this type of event is a chimera. More concretely, it is necessary to pay attention to the resilience of the system, so the goal must be the robustness (and perhaps even anti-fragility) of the socio-ecosystem with respect to any crisis advent, not the pursuit of the specific black swan, which, by the way, takes different forms: from financial perfect storms to pandemics, to the unpredictable effects of climate change etc. During the nineteenth century Europe was involved in various pandemics, which, among other things, stimulated the birth of regulatory plans and “hygienist” urban planning approach. Similarly, the present bursting of COVID-19 leads to ever greater efforts in the direction of environmental quality, which is also the protection of health. The paper refers to the health risk due to the urban characteristics, investigating the process of Urban Heat Island (UHI) which is a cause of health risk and of the increase in air pollution, while, at the moment, there is debate about the link between air pollution and COVID-19 diffusion, also if the first scientific papers on this topic seem to confirm the correlation. In any case, the precautionary principle pushes to take the opportunity of the crisis for a more sustainable city in terms of air breathing and wellness. This paper shows that it is possible to distinguish areas of the city with different UHI-air pollution hazard, according to their shape and land use. These results allow to support the choices of the planners to pursue mitigation of climatic extremes and air pollution, contributing to health of citizens and saving money from the health system.

Leone, Antonio, Pasquale Balena, and Raffaele Pelorosso. "Take advantage of the black swan to improve the urban environment." TeMA-Journal of Land Use, Mobility and Environment (2020): 247-259.

Building a Social Mandate for Climate Action: Lessons from COVID-19

The COVID-19 imposed lockdown has led to a number of temporary environmental side effects (reduced global emissions, cleaner air, less noise), that the climate community has aspired to achieve over a number of decades. However, these benefits have been achieved at a massive cost to welfare and the economy. This commentary draws lessons from the COVID-19 crisis for climate change. It discusses whether there are more sustainable ways of achieving these benefits, as part of a more desirable, low carbon resilient future, in a more planned, inclusive and less disruptive way. In order to achieve this, we argue for a clearer social contract between citizens and the state. We discuss how COVID-19 has demonstrated that behaviours can change abruptly, that these changes come at a cost, that we need a ‘social mandate’ to ensure these changes remain in the long-term, and that science plays an important role in informing this process. We suggest that deliberative engagement mechanisms, such as citizens’ assemblies and juries, could be a powerful way to build a social mandate for climate action post-COVID-19. This would enable behaviour changes to become more accepted, embedded and bearable in the long-term and provide the basis for future climate action.

Howarth, Candice, et al. "Building a social mandate for climate action: lessons from COVID-19." Environmental and Resource Economics (2020): 1-9.

Using the COVID-19 economic crisis to frame climate change as a secondary issue reduces mitigation support

The COVID-19 pandemic has understandably dominated public discourse, crowding out other important issues such as climate change. Currently, if climate change enters the arena of public debate, it primarily does so in direct relation to the pandemic. In two experiments, we investigated (1) whether portraying the response to the COVID-19 threat as a "trial run" for future climate action would increase climate-change concern and mitigation support, and (2) whether portraying climate change as a concern that needs to take a "back seat" while focus lies on economic recovery would decrease climate-change concern and mitigation support. We found no support for the effectiveness of a trial-run frame in either experiment. In Experiment 1, we found that a back-seat frame reduced participants' support for mitigative action. In Experiment 2, the back-seat framing reduced both climate-change concern and mitigation support; a combined inoculation and refutation was able to offset the drop in climate concern but not the reduction in mitigation support.

Ecker, Ullrich KH, et al. "Using the COVID-19 economic crisis to frame climate change as a secondary issue reduces mitigation support." Journal of Environmental Psychology (2020): 101464.

Greening the Post-pandemic Recovery in the G20

Rebuilding G20 economies after the COVID-19 pandemic requires rethinking what type of economy we need and want in the future. Simply reviving the existing 'brown' economy will exacerbate irreversible climate change and other environmental risks. For G20 economies, investing in a workable and affordable green transition is essential. A good place to start is learning what worked and what did not from previous efforts to green the economic recovery during the 2008–2009 Great Recession, examining the cases of the United States and South Korea. Policies for a sustained economic recovery amount to much more than just short-term fiscal stimulus. Transitioning from fossil fuels to a sustainable low-carbon economy will require long-term commitments (5–10 years) of public spending and pricing reforms. The priorities for public spending include support for private sector green innovation and infrastructure, development of smart grids, transport systems, charging station networks, and sustainable cities. Pricing carbon and pollution, and removing fossil-fuel subsidies, can accelerate the transition, raise revenues for the necessary public investments, and lower the overall cost of the green transition.

Barbier, Edward B. "Greening the Post-pandemic Recovery in the G20." Environmental and Resource Economics (2020): 1-19.

When pandemics impact economies and climate change: Exploring the impacts of COVID-19 on oil and electricity demand in China

Despite all the scientific and technological developments in the past one hundred years, biologic issues such as pandemics are a constant threat to society. While one of the aspects of a pandemic is the loss of human life, the outbreak has multi-dimensional impacts across regional and global societies. In this paper, a comparative regressive and neural network model is developed to analyze the impacts of COVID-19 (coronavirus) on the electricity and petroleum demand in China. The environmental analysis shows that the epidemic severeness significantly affects the electricity and the petroleum demand, both directly and indirectly. The outputs of the model stated that the elasticity of petroleum and electricity demand toward the population of the infected people is -0.1% and -0.65%, respectively. The mentioned results show that

pandemic status has a significant impact on energy demand, and also its impacts can be tracked into every corner of human society.

Norouzi, Nima, et al. "When pandemics impact economies and climate change: Exploring the impacts of COVID-19 on oil and electricity demand in China." Energy Research & Social Science 68 (2020): 101654.

Rethinking Air Quality and Climate Change after COVID-19

The world is currently shadowed by the pandemic of COVID-19. Confirmed cases and the death toll has reached more than 12 million and more than 550,000 respectively as of 10 July 2020. In the unsettling pandemic of COVID-19, the whole Earth has been on an unprecedented lockdown. Social distancing among people, interrupted international and domestic air traffic and suspended industrial productions and economic activities have various far-reaching and undetermined implications on air quality and the climate system. Improvement in air quality has been reported in many cities during lockdown, while the death rate of COVID-19 has been found to be higher in more polluted cities. The relationship between the spread of the SARS-CoV-2 virus and air quality is under investigation. In addition, the battle against COVID-19 could bring short-lived and long-lasting and positive and negative impacts to the warming climate. The impacts on the climate system and the role of the climate in modulating the COVID-19 pandemic are the foci of scientific inquiry. The intertwined relationship among environment, climate change and public health is exemplified in the pandemic of COVID-19. Further investigation of the relationship is imperative in the Anthropocene, in particular, in enhancing disaster preparedness. This short article intends to give an up-to-date glimpse of the pandemic from air quality and climate perspectives and calls for a follow-up discussion.

Ching, Joseph, and Mizuo Kajino. "Rethinking Air Quality and Climate Change after COVID-19." International Journal of Environmental Research and Public Health 17.14 (2020): 5167.

COVID-WAREHOUSE: A Data Warehouse of Italian COVID-19, Pollution, and Climate Data

The management of the COVID-19 pandemic presents several unprecedented challenges in different fields, from medicine to biology, from public health to social science, that may benefit from computing methods able to integrate the increasing available COVID-19 and related data (e.g., pollution, demographics, climate, etc.). With the aim to face the COVID-19 data collection, harmonization and integration problems, we present the design and development of COVID-WAREHOUSE, a data warehouse that models, integrates and stores the COVID-19 data made available daily by the Italian Protezione Civile Department and several pollution and climate data made available by the Italian Regions. After an automatic ETL (Extraction, Transformation and Loading) step, COVID-19 cases, pollution measures and climate data, are integrated and organized using the Dimensional Fact Model, using two main dimensions: time and geographical location. COVID-WAREHOUSE supports OLAP (On-Line Analytical Processing) analysis, provides a heatmap visualizer, and allows easy extraction of selected data for further analysis. The proposed tool can be used in the context of Public Health to underline how the pandemic is spreading, with respect to time and geographical location, and to correlate the pandemic to pollution and climate data in a specific region. Moreover, public decision-makers could use the tool to discover combinations of pollution and climate conditions correlated to an increase of the pandemic, and thus, they could act in a consequent manner. Case studies based on data cubes built on data from Lombardia and Puglia regions are discussed. Our preliminary findings indicate that COVID-19 pandemic is significantly spread in regions characterized by high concentration of particulate in the air and the absence of rain and wind, as even stated in other works available in literature.

Agapito, Giuseppe, Chiara Zucco, and Mario Cannataro. "COVID-WAREHOUSE: A Data Warehouse of Italian COVID-19, Pollution, and Climate Data." International Journal of Environmental Research and Public Health 17.15 (2020): 5596.

NO2 levels after the COVID-19 lockdown in Ecuador: A trade-off between environment and human health

The negative effects on human health, along with the fatalities caused by the new coronavirus, have led governments worldwide to take strict measures. However, a reduction in air pollution has been found in many regions on a global scale. This study is focused on how the COVID-19 pandemic is impacting on the air quality in Ecuador, one of the most alarming cases of COVID-19 contagion in Latin America, occupying the first place as regards deaths per capita. The spatio-temporal variations in NO2 concentrations in 12 highly populated cities were evaluated by comparing the NO2 tropospheric concentrations before (2019) and after (2020) the COVID-19 lockdown. The atmospheric data was collected from the TROPOMI on the Sentinel-5P satellite of the European Space Agency. A reduction in NO2 concentrations (-13%) was observed as a consequence of the COVID-19 lockdown in Ecuador. However, this reduction occurred to the greatest extent in the cases of Guayaquil (-23.4%) and Quito (-22.4%), the two most highly populated cities. Linking NO2 levels to confirmed cases/deaths of COVID-19, a strong correlation between air NO2 concentrations and the cases/mortality caused by coronavirus ($r = 0.91$; $p<0.001$) was observed. This work highlights the crucial role played by air quality as regards human health.

Pacheco, Henry, et al. "NO2 levels after the COVID-19 lockdown in Ecuador: A trade-off between environment and human health." Urban Climate 34 (2020): 100674.

Urban transport and COVID-19: challenges and prospects in low- and middle-income countries

The COVID-19 pandemic has recently forced half of humanity to experience an unprecedentedly expansive lockdown. Naturally, this has brought urban transport systems under a near standstill, which in turn resulted in a sharp drop in carbon emissions and levels of air pollution in affected areas. While the induced health and economic crisis is already lasting longer and affecting many more than originally expected, questions arise on what that means for the future of urban living, urban design and connectivity. A post-COVID-19 city could notably see a sustained drop in demand for commuting transport due to a combination of enduring economic crisis and changing work habits. It could experience a behavioural shift with regard to crowded spaces, and public transport in particular. In such context, this snapshot piece aims first at examining the possible consequences on public health of this scenario. Secondly, it uses system thinking to evaluate how stimulus plans could maximise social, health and climate co-benefits. It takes the example of populous middle-income countries to suggest a shift to investing in infrastructure focused on active travel modes, as the most prone to cheaply sustain hygiene, social-equity, reduced exposure to air pollution, reduced numbers of fatal accidents, and enhanced levels of physical activity.

Koehl, Arnaud. "Urban transport and COVID-19: challenges and prospects in low-and middle-income countries." Cities & Health (2020): 1-6.

The hidden positive effects of COVID-19 pandemic

The Coronavirus disease spread like fire, and millions of cases have been reported worldwide, and thousands have died. So, many countries around the globe ordered lockdown to stop the spread of the Coronavirus, which caused significant economic fallout. But every incident has two aspects, positive and negative. This article aimed to study the positive effects of COVID-19 pandemic on some specific factors and to study this topic, datais collected from various websites, web blogs, newspapers and reports on the internet. This pandemic enforced the cancellation or postponement of multiple events, which leads to a reduction in travelling and subsequently there were fewer vehicles on the road, which leads to a decrease in air and water pollution. Road traffic accidents and crime rate had come down suddenly. Due to lockdown, there was a reduction in transportation and industrial activity which allowed Mother Nature to

recharge and replenish. Due to lockdown, people spent quality time with their family, fulfilled their hobbies, learnt many new skills and understood the importance of sanitation, hand hygiene and social distancing. This pandemic is a lesson for us to learn many new things. This crisis revealed that there is a need to improve our healthcare system and clinical researches. Immunity of an individual can play an important role to fight these kinds of viral diseases, and these diseases can be avoided by simply following the basic concepts of the Ayurveda. This lockdown showed the short-term depletion in greenhouse gas emissions, but this is not an option for long-lasting climate change, and we have to think about a sustainable solution to save the environment.

Payal Sudhakar Kamdi, & Meena Shamrao Deogade. (2020). The hidden positive effects of COVID-19 pandemic. International Journal of Research in Pharmaceutical Sciences, 11(SPL1), 276-279.

Building Resilient, Smart Communities in a Post-COVID Era: Insights From Ireland

The COVID-19 pandemic spread rapidly throughout the world in early 2020. Beyond the substantial health impacts, the crisis has served as a catalyst for a dramatic shift in working practices, a greater reliance on technology, and a subsequent reduction in air pollution and greenhouse gas emissions in the most heavily populated parts of the planet. Indeed, the crisis has highlighted the interconnected nature of society's vulnerabilities while also demonstrating that transformational change is possible. These rapid changes have ignited debate around how to build more resilient societies and the role of planning in promoting equitable and sustainable recovery. This article presents key insights from Ireland, as policymakers grapple with these questions and the role of technology in ensuring ongoing delivery of services and a continuation of democratic processes. Specifically, this short article focuses on the impact of the pandemic on town centres and regional growth in Ireland and the potential interventions which can aid in addressing recently intensified local challenges.

Doyle, Aoife, William Hynes, and Stephen M. Purcell. "Building Resilient, Smart Communities in a Post-COVID Era: Insights From Ireland." International Journal of E-Planning Research (IJEPR) 10.2: 18-26.

Agricultural labor, COVID-19, and potential implications for food security and air quality in the breadbasket of India

To contain the COVID-19 pandemic, India imposed a national lockdown at the end of March 2020, a decision that resulted in a massive reverse migration as many workers across economic sectors returned to their home regions. Migrants provide the foundations of the agricultural workforce in the ‘breadbasket’ states of Punjab and Haryana in Northwest India.There are mounting concerns that near and potentially longer-term reductions in labor availability may jeopardize agricultural production and consequently national food security. The timing of rice transplanting at the beginning of the summer monsoon season has a cascading influence on productivity of the entire rice-wheat cropping system. To assess the potential for COVID-related reductions in the agriculture workforce to disrupt production of the dominant rice-wheat cropping pattern in these states, we use a spatial ex ante modelling framework to evaluate four scenarios representing a range of plausible labor constraints on the timing of rice transplanting. Averaged over both states, results suggest that rice productivity losses under all delay scenarios would be low as compare to those for wheat, with total system productivity loss estimates ranging from 9%, to 21%, equivalent to economic losses of USD $674 m to $1.48 billion. Late rice transplanting and harvesting can also aggravate winter air pollution with concomitant health risks. Technological options such as direct seeded rice, staggered nursery transplanting, and crop diversification away from rice can help address these challenges but require new approaches to policy and incentives for change.

Shirsath, Paresh B., et al. "Agricultural labor, COVID-19, and potential implications for food security and air quality in the breadbasket of India." Agricultural Systems 185 (2020): 102954.

Effect of COVID-19 virus on reducing GHG emission and increasing energy generated by renewable energy sources: A brief study in Malaysian context

Coronavirus 2019 (COVID-19) has globally affected the human mortality rate and economic history of the modern world. According to the World Health Organization, COVID-19 has caused a severe threat to the health of the vulnerable groups, notably the elderly. There is still some disagreements regarding the source of the virus and its intermediate host. However, the spread of this disease has caused most countries to enforce strict curfew laws and close most industrial and recreational centres. This study aims to show the potential positive effects of COVID-19 on the environment and the increase of renewable energy generation in Malaysia. To prevent the spread of this disease, Malaysia enacted the Movement Control Order (MCO) law in March 2020. Implementation of this law led to a reduction in environmental pollution, especially air pollution, in this country. The greenhouse gases (GHG) emission , which was 8 Mt CO2 eq. from January 2020 to March 2020, reduced to <1 Mt CO2 eq. for April and May. The reduction of GHG emission and pollutant gases allowed more sunlight to reach photovoltaic panels, hence increasing the renewable energy generation.

Naderipour, Amirreza, et al. "Effect of COVID-19 virus on reducing GHG emission and increasing energy generated by renewable energy sources: A brief study in Malaysian context." Environmental Technology & Innovation (2020): 101151.

The impact of air pollution on the incidence and mortality of COVID-19

Air pollution is the most significant environmental risk factor for all-cause mortality, and it has caused substantial disability-adjusted life-years and economic loss. Air pollution intensified the mortality during past pandemics, Spanish flu in 1918 and SARS-CoV-1 in 2003. It increases host susceptibility and virulence of respiratory infections and reduces viral clearance. Thus, a question arises whether there will be any impact of air pollution on the current pandemic coronavirus disease 2019 (COVID-19)? Thus far, history and science are directing towards an immense potential impact of air pollution on the COVID-19 pandemic. Some of the devastated countries with the current pandemic are those with a poor air quality index. Further epidemiological and ecological studies are necessary to confirm this association. Also, countries must mobilize funding for mitigation of air pollution to benefit environmental health and ameliorate its potential effects on pandemics of the future.

Karan, Abhinav, et al. "The impact of air pollution on the incidence and mortality of COVID-19." Global health research and policy 5.1 (2020): 1-3.

Changes of air quality and its associated health and economic burden in 31 provincial capital cities in China during COVID-19 pandemic

With outbreak of the novel coronavirus disease (COVID-19), immediate prevention and control actions were imposed in China. Here, we conducted a timely investigation on the changes of air quality, associated health burden and economic loss during the COVID-19 pandemic (January 1 to May 2, 2020). We found an overall improvement of air quality by analyzing data from 31 provincial cities, due to varying degrees of NO2, PM2.5, PM10 and CO reductions outweighing the significant O3 increase. Such improvement corresponds to a total avoided premature mortality of 9410 (7273–11,144) in the 31 cities by comparing the health burdens between 2019 and 2020. NO2 reduction was the largest contributor (55%) to this health benefit, far exceeding PM2.5 (10.9%) and PM10 (23.9%). O3 instead was the only negative factor among six pollutants. The period with the largest daily avoided deaths was rather not the period with strict lockdown but that during February 25 to March 31, due to largest reduction of NO2 and smallest increase of O3. Southwest, Central and East China were regions with relatively high daily avoided deaths, while for

some cities in Northeast China, the air pollution was even worse, therefore could cause more deaths than 2019. Correspondingly, the avoided health economic loss attributable to air quality improvement was 19.4 (15.0–23.0) billion. Its distribution was generally similar to results of health burden, except that due to regional differences in willingness to pay to reduce risks of premature deaths, East China became the region with largest daily avoided economic loss. Our results here quantitatively assess the effects of short-term control measures on changes of air quality as well as its associated health and economic burden, and such information is beneficial to future air pollution control.

Nie, Dongyang, et al. "Changes of air quality and its associated health and economic burden in 31 provincial capital cities in China during COVID-19 pandemic." Atmospheric Research (2020): 105328.

Effects of COVID-19 lockdown on global air quality and health

The COVID-19 pandemic has put much of the world into lockdown, as one unintended upside to this response, the air quality has been widely reported to have improved worldwide. Existing studies examine the environmental effect of lockdowns at a city- or country-level, few examines it from a global perspective. Using a novel COVID-19 government response tracker dataset, combining the daily air pollution data and weather data across 597 major cities worldwide between January 1, 2020, and July 5, 2020, this study quantifies the causal impacts of 8 types of lockdown measures on changes of a range of individual pollutants based on a difference-in-differences design. The results show that the NO2 air quality index value falls more precipitously (23–37%) relative to the pre-lockdown period, followed by PM10 (14–20%), SO2 (2–20%), PM2.5 (7–16%), and CO (7–11%), but the O3 increases 10–27%. Furthermore, intra/intercity travel restrictions have a better performance in curbing air pollution. These results are robust to a set of alternative specifications, including different panel sizes, independent variables, estimation strategies. The heterogeneity analysis in terms of different types of cities shows that the lockdown effects are more remarkable in cities from lower-income, more industrialized, and populous countries. We also do a back-of-the-envelope calculation of the subsequent health benefits following such improvement, and the expected averted premature deaths due to air pollution declines are around 99,270 to 146,649 among 76 countries and regions involved in this study during the COVID-19 lockdown. These findings underscore the importance of continuous air pollution control strategies to protect human health and reduce the associated social welfare loss both during and after the COVID-19 pandemic.

Chen, Fenglong, Meichang Wang, and Zhengning Pu. "Effects of COVID-19 lockdown on global air quality and health." Science of The Total Environment (2020): 142533.

Is Particulate Matter of Air Pollution a Vector of Covid-19 Pandemic?

The COVID-19 pandemic is a severe respiratory disease caused by the emergence of a new coronavirus, SARS-CoV-2, that very quickly spread in the human population. Fine particulate matter (PM) generated from combustion engines have been described as toxic to human health. Recent events stressed that high concentrations of PM of air pollution might favor the spread of SARS-CoV-2. Autumn approaches, air pollution will be accentuated because of weather condition. The risk of a second outbreak of Covid-19 pandemic is highly probable. Elucidating the role of PM of air pollution in the spread of the virus is thus urgent and crucial.

Barakat, Tarek, Benoit Muylkens, and Bao-Lian Su. "Is Particulate Matter of Air Pollution a Vector of Covid-19 Pandemic?." Matter 3.4 (2020): 977-980.

Improvement in ambient-air-quality reduced temperature during the COVID-19 lockdown period in India

The COVID-19 pandemic forced India as a whole to lockdown from 24 March 2020 to 14 April 2020 (first phase), extended to 3 May 2020 (second phase) and further extended to 17 May 2020 (third phase) and 31 May 2020 (fourth phase) with only some limited relaxation in non-hot spot areas. This lockdown has strictly controlled human activities in the entire India. Although this long lockdown has had a serious impact on the social and economic fronts, it has many positive impacts on environment. During this lockdown phase, a drastic fall in emissions of major pollutants has been observed throughout all the parts of India. Therefore, in this research study we have tried to establish a relationship among the fall in emission of pollutants and their impact on reducing regional temperature. This analysis was tested through the application of Mann–Kendall and Sen's slope statistical index with air quality index and temperature data for several stations across the country, during the lockdown period. After the analysis, it has been observed that daily emissions of pollutants (PM10, PM2.5, CO, NO2, SO2 and NH3) decreased by − 1– − 2%, allowing to reduce the average daily temperature by 0.3 °C compared with the year of 2019. Moreover, this lockdown period reduces overall emissions of pollutants by − 51– − 72% on an average and hence decreases the average monthly temperature by 2 °C. The same findings have been found in the four megacities in India, i.e., Delhi, Kolkata, Mumbai and Chennai; the rate of temperature fall in the aforementioned megacities is close to 3 °C, 2.5 °C, 2 °C and 2 °C, respectively. It is a clear indicator that a major change occurs in air quality, and as a result it reduced lower atmospheric temperature due to the effect of lockdown. It is also a clear indicator that a major change in air quality and favorable temperature can be expected if the strict implementations of several pollution management measures have been implemented by the concern authority in the coming years.

Pal, Subodh Chandra, et al. "Improvement in ambient-air-quality reduced temperature during the COVID-19 lockdown period in India." Environment, Development and Sustainability (2020): 1-28.

COVID-19 and agricultural fire pollution in the Amazon: Puzzles and solutions

In the Amazon, the quick spread of COVID-19 coincides with the high level of air pollution released during the "burning season", when thousands of square kilometres are prepared for agriculture. Mitigating health consequences by constraining fire use and social interaction is hindered by the dependence of local food security on fires, of enforcement on on-the-ground surveillance and of primary care on home visits. Based on fieldwork experience, alternatives to test potential solutions to the policy puzzles are proposed, highlighting the role of smallholder mechanization and of community health workers (CHWs). It is argued that randomized control trials could be designed to assess the effectiveness of tractor scheduling workshops, grassroots-based tractor administration, mobile-health-aided data collection by CHWs and data-driven algorithms to plan their home visits. The need for researcher-practitioner collaboration for optimized targeting of on-the-ground illegal fire deterrence is also stressed. The trials and the potential solutions to be trialled are more likely to be successful whether integrated into a broader and perennial process of research and development of interventions for sustainable development of the Amazon, whose need was widely revealed by the ongoing pandemic.

Morello, Thiago Fonseca. "COVID-19 and agricultural fire pollution in the Amazon: puzzles and solutions." World Development (2020): 105276.

Towards baseline air pollution under COVID-19: implication for chronic health and policy research for Delhi, India.

The Megacity of Delhi, home to 19 million inhabitants, is infamous for its poor air quality mainly due to anthropogenic emissions. While the COVID-19 pandemic is a health emergency, lockdown due to it saw an unprecedented decline in emission sources of pollutants by ~85%-90% in Delhi, resulting in sharp decline in the concentration of majority of pollutants. Here we report the experimental estimate of baseline level

that is defined as the minimum level reached after lockdown under consistent fair weather condition of major criteria pollutants. This may be considered as an indicator of the background levels to which the population is chronically exposed. The consequences of such chronic air pollution exposure are excess respiratory and cardiovascular morbidity and mortality which are reported to be more serious than severe pollution episodes by epidemiologists. As the lockdown which was imposed on 24 March 2020, was extended during April and May, we present the prevailing ambient pollution levels and compare them with the baseline levels. Results are based on India's largest monitoring network of 34 stations in Delhi. The findings are critical for policymakers to fine-tune ambient air quality standards and regulations leading to the development of effective risk management policies and control strategies.

Beig, Gufran, et al. "Towards baseline air pollution under COVID-19: implication for chronic health and policy research for Delhi, India." Current Science (00113891) 119.7 (2020).

Exploring the linkage between PM2.5 levels and COVID-19 spread and its implications for socio-economic circles

A pneumonia-like disease of unknown origin caused a catastrophe in Wuhan city, China. This disease spread to 215 countries affecting a wide range of people. World health organization (WHO) called it a pandemic and it was officially named as Severe Acute Respiratory Syndrome Corona virus 2 (SARS CoV-2), also known as Corona virus disease (COVID-19). This pandemic compelled countries to enforce a socio-economic lockdown to prevent its widespread. This paper focuses on how the particulate matter pollution was reduced during the lockdown period (23 March to April 15, 2020) as compared to before lockdown. Both ground-based and satellite observations were used to identify the improvement in air quality of Pakistan with primary focus on four major cities of Lahore, Islamabad, Karachi and Peshawar. Both datasets have shown a substantial reduction in PM2.5 pollution levels (ranging from 13% to 33% in case of satellite observations, while 23%–58% in ground-based observations) across Pakistan. Result shows a higher rate of COVID-19 spread in major cities of Pakistan with poor air quality conditions. Yet more research is needed in order to establish linkage between COVID-19 spread and air pollution. However, it can be partially attributed to both higher rate of population density and frequent exposure of population to enhanced levels of PM2.5 concentrations before lockdown period.

Ali, Syeda Mahnoor, et al. "Exploring the linkage between PM2. 5 levels and COVID-19 Spread and its implications for socio-economic circles." Environmental Research (2020): 110421.

REPORTING ON EMERGING RESEARCH

COVID-19 Could Help Solve Climate Riddles: Pollution declines from pandemic shutdowns may aid in answering long-standing questions about how aerosols influence climate

Levy, Adam. COVID-19 Could Help Solve Climate Riddles. Scientific American *(17 April 2020)* *https://www.scientificamerican.com/article/covid-19-could-help-solve-climate-riddles1/*.

A COVID-19 recovery for climate

Daniel Rosenbloom, Jochen Markard. A COVID-19 recovery for climate. Science (01 May 2020)

https://science.sciencemag.org/content/368/6490/447

We’re flattening the coronavirus curve. We can flatten the climate curve, too

A. R. Ravishankara and Mary M. Glackin.

https://www.washingtonpost.com/outlook/2020/05/19/coronavirus-action-climate-change/

What can COVID-19 teach us about responding to climate change?

Mario Herrero and Philip Thornton, https://doi.org/10.1016/S2542-5196(20)30085-1

https://www.sciencedirect.com/science/article/pii/S2542519620300851

Compound climate risks in the COVID-19 pandemic

Phillips, C.A., Caldas, A., Cleetus, R. et al. Compound climate risks in the COVID-19 pandemic. Nat. Clim. Chang. (2020). https://doi.org/10.1038/s41558-020-0804-2

https://www.nature.com/articles/s41558-020-0804-2#citeas