**The New York Times**

**Pandemic’s Cleaner Air Could Reshape What We Know About the Atmosphere**

Coronavirus shutdowns have cut pollution, and that’s opened the door to a “giant, global environmental experiment” with potentially far-reaching consequences.

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**THE WALL STREET JOURNAL**

**ECONOMY**

**Coronavirus Lockdowns Clear the Air, but the Green Effect Could Be Fleeting**

Some worry long-term environmental efforts will suffer as governments look to stimulate growth.

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**The Guardian**

**Covid-19 lockdowns have improved global air quality, data shows**

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**The Washington Post**

**Washington has its cleanest spring air in 25 years: How air quality has improved during the coronavirus crisis**
Literature review process: Response to the pandemic

Information per publication manually catalogued

- Percent change of pollutant concentrations
- Absolute pollutant concentrations
- the region and periods studied,
- Methods to measure
  - Ground-based
  - Satellites
- First author
- Journal name
- Dates of submission, acceptance,
- How authors may or may not have accounted for the effects of seasonality/meteorology.
- ... and more
Literature review process: Response to the pandemic

Cumulative number of papers (N) used in this study

Data Type
- both
- satellite
- ground
  - discussed but not corrected
  - not discussed or corrected

Meteo Analysis
- modeling
  - corrected for meteorology/seasonality

Year 2020

Cumulative papers by:
- submission date
- accepted date

1st paper accepted

W.H.O declares COVID-19 pandemic

Papers by Study Region:
- All Other Regions
- Southeast Asia
- South Asia
- South America
- North America
- West Asia
- East Asia
- Europe

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct

N. & S. America

W. Asia

E. Asia

Europe
How drastic changes do we expect? 

**BEFORE**

Before Lockdown
Reference period

**LOCKDOWN**

During Lockdown
Lockdown period

How much are we expecting transportation to contribute to the overall emissions?
The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

\[ \text{NO}_x: \ 36\% \ (15–51\%) \]
Inventory-based business as usual emission scenario

The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

\[ \text{NO}_x: \quad 36\% \ (15-51\%), \]
\[ \text{PM}_{2.5}: \quad 8\% \ (3-19\%), \]
The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

\[ \text{NO}_x: \quad 36\% \ (15\% - 51\%), \]
\[ \text{PM}_{2.5}: \quad 8\% \ (3\% - 19\%), \]
\[ \text{CO}: \quad 30\% \ (5\% - 70\%) \]

\[ \text{NO}_2 > \text{CO} > \text{PM}_{2.5} \]
Stringency index as a metric for lockdown measures

Categories included are:

- the implementation and extent of school closures
- implementation and extent of workplace closures
- restrictions on public events
- Gatherings
- closure of public transport
- degree of public information campaigns
- extent of measures to enforce stay-at-home
- restrictions on internal movement,
- international travel
- testing policy, and
- contact tracing.

As such the index includes both measures that impact emissions and measures with no obvious consequence for emissions.

https://ourworldindata.org/grapher/covid-stringency-index
We did our own bit of analysis first.

Difference in NO$_2$ column concentrations based on the TROPOMI measurements for 2020 compared to 2019.

Stringency index is used for April as a representative month for the most stringent conditions globally. China is an exception where lockdown measures were implemented in February-March and relaxed in April.
Data included in the upcoming analysis

- Data included in the upcoming analysis includes:
  - Satellite data
  - Meteo & Long-term trends
  - Both

- Papers by study region:
  - All Other Regions
  - Southeast Asia
  - South Asia
  - South America
  - North America
  - West Asia
  - Europe
  - East Asia

- Papers by platform used:
  - Both
  - Satellite only
  - Ground-based only
  - Meteo & long-term trends not discussed
  - Discussed, not quantified
  - Quantified
  - Modeling

- Methodology used:
  - Platform: Used
  - Method: Used

- Cumulative number of papers used in the study:
  - Year 2020
  - E. Asia
  - Europe
  - W. Asia
  - N. & S. America
  - S. Asia
  - W.H.O declares COVID-19 pandemic
  - 1st paper accepted
Observed changes as percentage difference

(NO_2, NO_x, and CO have the largest expected contribution from transportation)

(PM_{2.5} and O_3 as the most relevant pollutants for health impacts that are also secondary;)

(N/N) = (number of publications / number of datasets)
Observed changes as percentage difference

SO$_2$, NH$_3$, and non-methane volatile organic compounds (NMVOCs) mostly related to primary gas-phase emissions,

PM$_{10}$, aerosol optical depth (AOD), black carbon (BC), and air quality index (AQI).
• Emission of primary pollutants are expected to decrease as the lockdown measures become stricter

• It is essential to account and quantify the effects of meteorology to quantitatively link changes in atmospheric abundance with changes in emissions
Comparison of observations to the Forster inventory

- Agreement within a factor of 2, within the associated uncertainties.
- The stringency of lockdown measures has a strong relationship with levels of traffic.
- The similarity between changes in the emissions inventory and atmospheric observations due to COVID-19 lockdown measures suggests the importance of traffic as a source of NOx in cities around the world.

Forster et al. (2020), Nature
O$_3$ percent changes and correlation to stringency index

Forster et al. (2020), Nature
PM$_{2.5}$ and SO$_2$ observations compared to the Forster inventory

Forster et al. (2020), Nature
Absolute concentrations: Lockdown vs. Reference periods

(NO/N) = (number of publications / number of datasets)

NO\textsubscript{2} concentration (µg m\textsuperscript{-3})
-40 ± 26%

PM\textsubscript{2.5} concentration (µg m\textsuperscript{-3})
- 21 ± 13%

O\textsubscript{3} concentration (µg m\textsuperscript{-3})
+ 21 ± 19%
How well do we understand PM$_{2.5}$ and O$_3$?

What is the chemical composition of PM$_{2.5}$?

What happens in chemically active seasons?
What is the role of secondary PM$_{2.5}$ on air quality?

In China during lockdowns PM$_{2.5}$ % even increased

Le et al., Science, (2020)
What is the role of secondary PM$_{2.5}$ on air quality?

In China during lockdowns PM$_{2.5}$ % even increased

Guo et al., PNAS, 2014

Gkatzelis et al., GRL, 2021

POA SOA nitrate sulphate ammonium chloride
What is the role of secondary PM$_{2.5}$ on air quality?

In China during lockdowns PM$_{2.5}$ % even increased

- Guo et al., PNAS, 2014
- Gkatzelis et al., GRL, 2021

- Secondary PM represent the dominant fraction of the mass

Le et al., Science, (2020)

Nault et al., ACP, (2021)
PM$_{2.5}$ concentrations and precursor compound reductions

PM guideline values are still exceeded

PM$_{2.5}$ concentration (µg m$^{-3}$)

Understudied PM precursors

WHO guideline values

Observed percentage change
How do VOC emissions change during lockdowns?

- To get $O_3$ right you need both NO$_X$ and VOC emission reductions
- NO$_X$ emission reductions can be quantified relatively well
- But which VOC emission sectors are expected to change though?

**Expectation**

- reductions
- unknown
Importance of residential emissions in urban environments

- Volatile chemical products (VCPs) contribute significantly to urban VOC emissions in the US.
- Places with drastically different population densities show high fraction of VCPs.
- Do these emissions contribute to O₃ production?

Gkatzelis et al., ES&T, 2021
O₃ formation in New York City during a heatwave

July, 2018

Total AVOC Emissions

<table>
<thead>
<tr>
<th>Source</th>
<th>Emissions (t)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Exhaust</td>
<td>0.75</td>
<td>52%</td>
</tr>
<tr>
<td>Gas Fuel Diesel</td>
<td>0.35</td>
<td>32%</td>
</tr>
<tr>
<td>Coatings</td>
<td>0.27</td>
<td>44%</td>
</tr>
<tr>
<td>Adhesives Pesticides</td>
<td>0.51</td>
<td>42%</td>
</tr>
<tr>
<td>Personal Care Cleaning</td>
<td>0.23</td>
<td>53%</td>
</tr>
</tbody>
</table>

Produced O₃

| Emissions (total = 2.5 t) | 0.92 |

Quantifying changes in residential VOC emissions will be essential in accurately determining O₃ during the lockdown periods.

NOAA Instrumented Mobile Laboratory in NYC

Coggon et al., (2021), in press
How could wildfire season affect O₃ formation in lockdowns

Radical production & termination balance

- Fast transition to a NOₓ sensitive regime
- O₃ production expected to increase moving over an urban environment
- Periods influenced by biomass burning will be challenging to compared to previous years

Robinson et al., (2021), in review
Concluding Remarks

1. Importance of Accounting for the Effects of Meteorology and Long-term Trends

1. Statistics for certain pollutants is good but for other not.

2. Comparisons to emission inventories is good for NO$_2$ but for other pollutants more work is required

4. A logarithmic O$_3$ increase with increasing stringency index is evident
Future Recommendations


2. Changes in PM$_{2.5}$ may enable similar sensitivity analyses to primary emissions. A larger analysis of chemically speciated PM$_{2.5}$ data, where available, will be especially informative.

3. Expansion of the available analyses to include a larger number of short-lived species would help to constrain and inform emissions inventories.

4. Analysis of the radiative forcing associated with short-lived climate forcers is a priority.

5. This review has been limited in scope to short-lived air pollutants that are relevant to air quality and climate, but not to longer lived species such as CH$_4$, CO$_2$, N$_2$O and halogenated short lived climate forcers.
Online Database Available Now!

Rita Gomes
Michael Decker

Download data but also submit your own

https://covid-agq.fz-juelich.de/

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