Introduction

Have you ever seen brown air over a city? When people burn fuel in cars, homes, and factories, the smoke and exhaust go into the air. Breathing in pollutants can irritate your throat and lungs. People who live in places with poor air quality are more likely to get sick. About 7 million people die every year because of poor air quality.

Air pollution can come from human activity or from natural sources (See Fig.1 on Page 2). Power plants, factories, traffic, and farms are examples of human-caused air pollution. Air quality can also be bad during natural events like dust storms, forest fires, and volcanic eruptions. Knowing where pollution is coming from helps us know how we can fix it!

At the beginning of the worldwide COVID-19 pandemic, many countries went into lockdown. During lockdowns, people had to stay home as much as possible. In some places, people noticed clearer skies and cleaner air. Is it possible that this change in how much people and goods moved around makes the air quality better?

To answer this question, we needed to know:

1. Was the amount of air pollution lower during lockdowns than it would have been otherwise?

2. Did places where people drove less also have less pollution?
We focused on three different pollutants:

1. Nitrogen dioxide (NO₂),
2. Ozone (O₃), and
3. Fine particulate matter (PM₂.5).

We measured the concentration of each pollutant using data from satellites and weather stations. Satellite data let us measure the average over entire countries. The weather stations are usually in cities and measure the concentration at ground level.

Air pollution is affected by the weather. We wanted to make sure that any differences that we saw during COVID lockdowns actually came from lockdowns, and not just from the weather being different. So we kept track of how air pollution responds to changes in temperature, wind, rain, and humidity. We used that information to calculate the amount of pollution we would expect for each day.

We also needed to know how much people were driving. Google and Apple both made human mobility data available to anyone who wanted it. Google’s data told us how many people were going to and from work. Apple’s data told us how often people searched for driving directions. We assumed that if people look up driving directions less, they also are driving less.
Results

We found that during lockdown events:

1. NO₂ concentrations went down by 60%.
2. PM₂.₅ concentrations went down by 31%.
3. Ozone went up in some places and down in other places.

We found that NO₂ concentrations decreased when people drove less. We did not see a relationship between driving and ozone or PM₂.₅ concentrations. (See Fig. 2)

Figure 2:
Concentration of NO₂, O₃, and PM₂.₅ since the start of lockdown compared to the expected amount. We calculated the expected amount using pollution and weather measurements from the previous three years. The solid line shows the pollution level during lockdown. The dashed line shows the expected amount, and the gray band shows the range of likely pollution levels.

Discussion

Poor air quality can happen for lots of different reasons. It’s important to think about what makes each country and community unique. Although we saw clear reductions in NO₂ and PM₂.₅ overall, there were differences from place to place.

Lockdown orders resulted in people driving less. Many small businesses and factories stopped working. But power plants, farms, and some other kinds of industry kept going. So, in places where exhaust from gas-powered cars, trucks, and buses makes up a large part of the air pollution, lockdowns lowered emissions a lot. But in places where air pollution is mostly from power plants or farms, lockdowns didn’t result in lowered air pollution.

In Thailand and Australia, PM₂.₅ levels went up in 2020. That’s probably because wildfire smoke increased air pollution more than lockdowns decreased it.

Ozone decreased in some places and increased in others. Ozone chemistry is more complicated than NO₂ chemistry. Ozone also stays in the air longer. Depending on what else is in the air, and how sunny it is, chemical reactions in the air can either form new ozone molecules or break them apart.
Conclusion

Nobody wants to have another lockdown. Having to stay inside makes it hard to stay connected with friends and family. And it makes it hard for people to do their jobs. Up to the current moment in the COVID pandemic, more than 200 million people have gotten sick, and more than 4 million people have died. It is a tragedy that we will remember for the rest of our lives.

Air pollution also causes millions of people to get sick and die every year. Some of that is due to indoor pollution, such as smokey open fire stoves. Bad air quality outside can come from smokestacks, vehicles, and forest fires. Our results show that if we change the way we get around, we can enjoy better air quality. When you choose to walk or bike, you are helping your community have cleaner air!

Glossary of Key Terms

- **Air quality** - A measure of the amount of pollution in the atmosphere. High air quality means the air is relatively free of pollution, and low air quality means there is a lot of pollution in the air.

- **Concentration** - The amount of pollution in the air. Usually, pollution concentration is reported as the weight of pollutants per cubic meter of air.

- **Fine particulate matter (PM2.5)** - Airborne particles that are less than 2.5 microns across.

- **Fuel** - Material that is burned for energy. Cars usually use gasoline or diesel fuel. Power plants using older technology often burn coal or natural gas for fuel.

- **Goods** - Stuff. All our material production.

- **Human mobility** - People moving around. Here, human mobility refers to people riding in or driving buses, cars, and trucks. In this study, the data were provided by Google and Apple.

- **Lockdown** - A government policy limiting when people could go out of their homes. For example, in many countries, public areas, schools, and offices were closed for some time in 2020 to try and keep people from catching COVID-19.

- **Micron** - One-millionth of a meter.

- **Nitrogen dioxide (NO2)** - A gas made up of one nitrogen atom and two oxygen atoms. Nitrogen dioxide in the atmosphere usually comes from vehicle exhaust. Not only is it harmful by itself, it reacts with other chemicals in the air to make many different pollutants.

- **Ozone (O3)** - A gas made up of three oxygen atoms that forms naturally in the stratosphere, and as a pollutant at ground level.

- **Pollutant** - Any harmful substance in the environment.

- **Stratosphere** - The second layer of the atmosphere as you go upward. It is located above the troposphere and below the mesosphere.

- **Ultraviolet (UV) radiation** - a form of energy that is emitted by the sun and artificial sources, such as tanning beds. While it has some benefits for people, including the creation of Vitamin D, it also can cause health risks.

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Check your understanding

1. We suggested that forest fires made it so that pollution went up in some places, despite people driving less. What other factors can you think of that would make air quality worse?

2. Why did we need to think about the weather?

3. Why should anyone care about air pollution?

4. In many communities, it is difficult or unsafe to walk or bike. What would you change in your community to make it easier and safer for people to walk or bike?

REFERENCES

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Authors’ tool for exploring air pollution changes during COVID-19 lockdowns: https://nina.earthengine.app/view/lockdown-pollution

US Environmental Protection Agency (EPA): 6 common air pollutants https://www.epa.gov/criteria-air-pollutants