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Sulfur dioxide and nitrogen oxides during the COVID-19 pandemic

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While the effects of sulfur dioxide and nitrogen oxides are widely recognised and have been for many decades, their subsequent effects since the beginning of the COVID-19 pandemic follow unique trends. This Environmental Brief focuses on the difference in effects shown before and during the pandemic.

Sources

Sulfur dioxide (SO_2) is naturally released into the atmosphere in large quantities through erupting volcanoes, and by human activities such as combustion of fossil fuels and smelting of sulfur-containing mineral ores. In the UK, 236,900 metric tons of sulfur dioxide were released in 2018 alone, despite the general trend of yearly reductions in compliance with international agreements within the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) and some Sulfur Protocols within the European Union (Queensland Government, 2020).

In the UK alone, around 2.2 million tons of nitrogen oxides are released each year, with 50% of these from motor vehicles and 25% from power stations.

Nitrogen oxides (NO_x) comprise both nitric oxide (NO) and nitrogen dioxide (NO_2) and, like sulfur dioxide, are produced both naturally and due to human activities. NO_x are produced naturally through lightning strikes and microbial processes in soils. However, they are largely produced by combustion processes involving nitrogen compounds and the combination of oxygen and nitrogen. In the UK alone, around 2.2 million tons of nitrogen oxides are released each year, with 50% of these from motor vehicles and 25% from power stations. Like sulfur dioxide, the trend for NO_X emissions in the UK sees yearly reductions; largely due to compliance with protocols such as the 1988 Sofia Protocol concerning the volume of nitrogen oxides emissions.

Impacts

It is well known that the major environmental role of atmospheric SO_2 and NO_x is in the production of acid rain and its subsequent harmful effects on the environment. This is an umbrella term indicating acidic precipitation, usually with a pH of between 4.2 and 4.4, containing sulfuric or nitric acid, falling from the atmosphere as either wet or dry deposition (*1*). When SO_2 and NO_x are released, they may react with water and oxygen in the atmosphere. Newly formed acidic precipitation may be transported long distances by prevailing air currents, creating problems not only for those close to emission sources, but possibly stretching over hundreds of miles (*2*). Wet deposition will fall from the atmosphere as rain, snow, or hail, while dry deposition will form in the absence of moisture in the form of particles and gases, later mixing with water during proceeding rainfall events. Acid rain can enter water systems, penetrate soils, and run across the surface via runoff water. This acidity can cause major ecological effects on bodies of water such as lakes and streams because acid rain slowly makes waters more acidic. Acid rain also causes harm to vegetated environments and impacts human health. Acid rain also causes harm to vegetated environments and impacts human health.

Aquatic environments Acidification of waters leads to a higher dissolution rate of aluminium from soils to waters, creating a toxic environment for aquatic animals. This is particularly apparent in aquatic organisms such as clams, which require a pH of 6 or above to survive, leading to their death in waters toxified by acid rain (*1*). Interconnected ecosystems suffer secondary impacts from this acid rain because species at the base of aquatic food chains decline in number; eventually being unable to support non-aquatic species.

Vegetated environments An abundance of aluminium released from the soils, along with essential nutrients such as calcium disappearing from soils impacted by acid rain, can cause vegetated areas to suffer immensely. These factors inhibit the ability of water being absorbed and taken up by trees and plants, and acidic rainfall can directly harm leaves, flowers, and needles. Acidification can leave vegetation in an unhealthy state due to an inability to absorb critical levels of essential nutrients, leading to a higher chance of disease and lower reproduction rates (*2*).

Human impacts Physical structures such as limestone buildings can be damaged by acid deposits, as may other structures such as cars. Health problems such as asthma and eye irritation may arise when acid precipitation takes the form of inhalable fog (*2*).

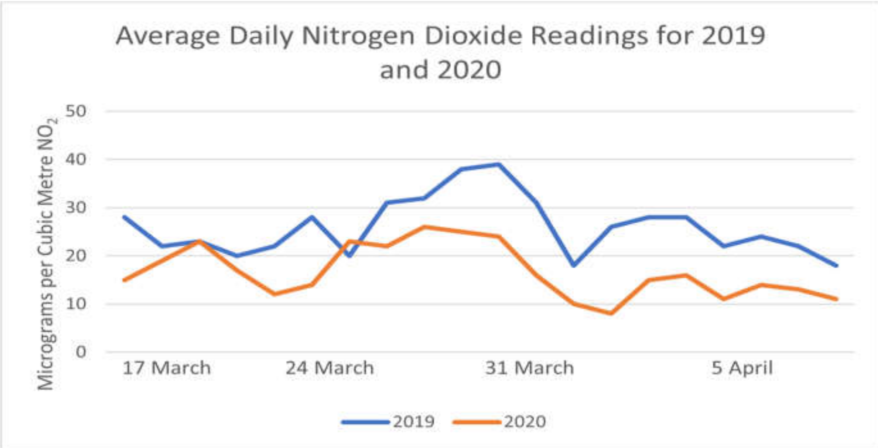

Figure 1. Graph comparing nitrogen dioxide levels between 2019 and 2020 showing over 50% reduction during lockdown, data from Khoo et al (3) .

Since the pandemic

During the countrywide lockdown in the United Kingdom imposed on March 23rd, 2020, anthropogenic movements were rapidly supressed. During the first 100 days of the lockdown, a significant reduction in air pollution levels were noted, compared to the same time period over the previous seven years. On average across the United Kingdom, NO_x levels were much lower for this period – approximately 50% lower – whilst SO_2 levels rose by over 50%. **Figure 1** illustrates the vast reduction of nitrogen dioxide levels recorded since the first day of the March 2020 UK lockdown, compared with data from the year before.

Data from the UK Department for Transport suggest that vehicle transport on the first day of lockdown was at 69% of its usual volume and, by April 13th, this had reduced to 23%. Since motor vehicle traffic accounts for the majority of the NO_x emissions in the United Kingdom, the 77% decrease in motor transport by April 13th led to a huge decrease in NO_x emissions. The decrease in NO_x and particulate matter during this time resulted in a positive effect on air quality, temporarily reducing the volume of NO_x available in the atmosphere to react with water and oxygen. This improvement in air quality reduced the volume of acidic precipitation in the UK, and nearby countries, improving the quality of aquatic and vegetated areas and temporarily benefiting human health by alleviating conditions such as asthma or eye irritations due to the reduction in acidic inhalable fog (*3, 4*). However, an increase of SO_2 emissions of over 100% has been observed during the March 2020 lockdown. Despite a reduction in motor vehicle traffic, SO_2 levels more than doubled across the United Kingdom since March 23rd. Data from the Met Office regarding weather and humidity suggest that the decrease in NO_x emissions, along with the approximate 10% increase in ozone levels, may have had a profound impact on the air chemistry close to the surface of the earth, affecting humidity. Studies show a direct correlation between SO_2 and relative humidity and, following data for 100 days after the beginning of lockdown, high humidity levels were recorded across the United Kingdom.

High humidity leads to a wet surface reduction, meaning less rain, which directly removes a natural sink for SO_2. This directly correlates to a higher proportion of SO_2 within the atmosphere due to less being held in sinks, accounting for the 100% increase seen during the lockdown period. This, in turn, neutralises the positive health and environmental benefits seen from a reduction of NO_x, since the vast increase in atmospheric SO_2 creates a greater opportunity for acidic rain and its associated negative impact on ecosystems and human health (*3, 4*).

References

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