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Effects of Global Lockdown on Ozone Layer: Studying the Atmospheric Changes during Covid-19 Pandemic Era

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Abstract

The COVID–19 worldwide pandemic prompted strict lockdowns globally with human activities, including travel, heating, and industrial operations, coming to a standstill. This paper analyses the effects of the pandemic lockdowns on the ozone layer by studying data captured during the COVID–19 period. We examine satellite and meteorological data, ground observation networks, and model output to quantify ozone level Precursor (nitrogen oxides and volatile organic compounds) emissions and precursors along with a host of other atmospheric constituents. The remote sensing data indicated significant improvements in O3 concentrations in some regions attributed to lesser consumption of ozone depleting substance (ODS) and pollutants. The drastic O3 changes trapped the attention of researchers who analyzed the correlation of lower pollutant levels and the intricate process of ozone reactions within the atmosphere's boundary layer

Keywords: Covid-19; Lockdown; Pollution; Ozone Layer; Emissions; Atmospheric Changes; Ozone Depleting Substances; Stratosphere.

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Introduction

The growth of the Coronavirus (Covid-19) pandemic in December 2019 from Wuhan, China, caused by SARSCoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) had drastic economic, social and atmospheric disruption around the world [1]. Numerous countries applied lockdown to prevent the transmission of the disease which played a crucial role for our environment as well. The implementation of strict lockdowns involved the temporary closure of unessential businesses, mobility limitations and social distancing. One area that assembled empirical attention is the impact of human activity on the atmosphere, especially the ozone layer of the Earth - a shield in the Earth's stratosphere that absorbs harmful ultraviolet radiation.

Ozone layer is located withinside the decrease part of the stratosphere and includes excessive awareness of ozone (O_3) [2]. It is positioned 10-50 km the above Earth and blocks dangerous ultraviolet UV-B and UV- C radiation coming from the Sun. The release of chlorofluorocarbons (CFCs) has led to ozone depletion because of human activities, and has been summarized in subsequent review [3]. Strict lockdowns remarkably decreased commercial activity, vehicular emissions, and air travel during Covid-19 pandemic. As a result, drop in air pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO), volatile organic compounds

(VOCs) and particulate matter ($PM_{2.5}$, PM_{10}) was noted [4]. NO_2 breaks down protective ozone via catalytic cycles whereas, CO reduce OH radicals affecting ozone chemistry indirectly. During lockdowns, ozone reductions showed noticeable regional patterns due to variations in climate conditions, emission sources and atmospheric circulation. Clearer skies and fewer pollutants provided better conditions for ozone formation. Several media outlets reported noticeable ozone layer recovery during global lockdown [5].

Need for Review

A systematic literature review is hence important to study findings related to atmospheric changes during pandemic era and their impact on ozone chemistry. Such a review helps to identify the knowledge gaps, bring clarity for conflicting results, and support overall understanding of whether- and in what manner - temporary emission reductions influenced atmospheric changes and recovery process of the ozone layer. This also helps to understand how global behaviour can affect atmosphere - such as changes in air quality, ozone concentrations, and greenhouse gas levels. This can guide future environmental policy and crises [6].

Methodology

This systematic review provides a review of COVID-19 lockdown atmospheric impacts (2020-2021) from in-depth examination of peer-reviewed literature and proven satellite data sets. Our approach adheres to guidelines for environmental systematic reviews [12], with four main phases:

- We performed searches in various databases:
- Web of Science (for top-tier atmospheric research) [13]
- Scopus (for full coverage of earth sciences) [14]NASA Earth data (for satellite data products) [10]
- ESA Earth Online (for Copernicus mission data) [11]

Findings and Thematic Analysis

The COVID-19 pandemic and subsequent lockdowns across the globe created an unprecedented opportunity to observe the direct impacts of reduced human activity on air quality. One of the most consistent findings was a marked reduction in key air pollutants, particularly nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$ and PM_{10}), and carbon monoxide (CO).

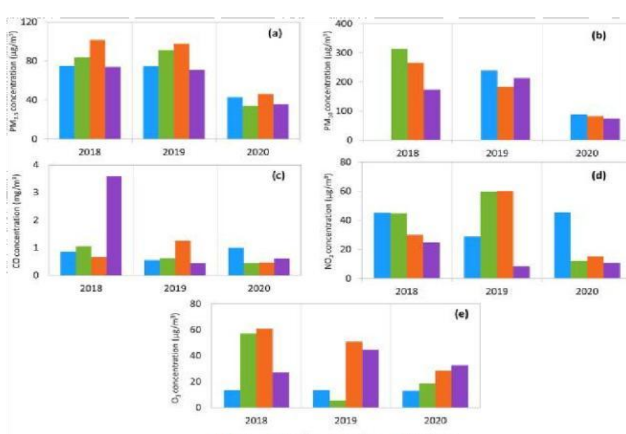

Fig. 1. *Variation of air pollutant (a) NO2, (b) surface O3 and (c) CO before and after lockdown.[15]*

For instance, significant NO_2 declines— ranging from 20% to over 60%—were documented across urban centers worldwide, mainly due to decreased traffic and industrial emissions [7][9][8] Similarly, $PM_{2.5}$ and PM_{10} levels dropped by approximately 10% to 40%, though the extent varied based on local emission sources and meteorological conditions.

This phenomenon is attributed to the complex photochemistry of the atmosphere—specifically, the reduction in NO_x emissions can lead to less ozone being broken down, resulting in higher ambient O_3 levels [8][7]. In conclusion, the global lockdowns served as a real-world experiment in reducing emissions, revealing both the responsiveness of atmospheric systems and the scale of human impact on air quality. The studies collectively advocate for leveraging this experience to inform future environmental policy and urban planning strategies.

Discussion

The COVID-19 pandemic created a global lockdown like never before, drastically changing human activities including industrial processes, transportation, and energy consumption. These changes created a special situation to study the effect of anthropogenic emission reductions on atmospheric chemistry, especially the ozone layer.

The lower nitrogen oxides (NO_x), volatile organic compounds (VOCs), and other pollutants had localized impacts on ozone concentrations. Although the recovery patterns of the ozone layer have since been associated with the phase-out of ozone-depleting substances (ODS) in the Montreal Protocol, the lockdown period provided further insights into the interaction of human activity and ozone processes.

Table. 1. Daily average concentration of air pollutants before and after lockdown and its change in percentage of 15 cities in India. [16]

City	PM2.5 Before	PM2.5 After	PM10 Before	PM10 After	SO_2 Before	SO_2 After
Ahmedabad	61.98	30.67	134.69	80.93	53.03	26.75
Asansol	69.71	32.52	137.84	76.70	19.74	12.57
Bengaluru	31.61	29.15	None	None	5.77	6.72
Chennai	46.13	25.81	None	None	24.00	3.08
Delhi	100.83	81.31	147.34	106.05	17.78	13.32
Ghaziabad	104.48	45.99	199.61	105.58	14.12	17.43
Hyderabad	47.54	33.37	None	None	10.30	7.33
Jaipur	35.38	22.08	93.04	61.44	13.06	11.07
Kanpur	107.37	62.52	None	None	4.86	4.39
Kolkata	69.09	25.40	140.23	45.99	13.76	10.16
Lucknow	107.37	62.52	None	None	4.86	4.39
Mumbai	36.62	24.35	101.92	64.82	13.87	33.47
Nagpur	34.80	23.33	67.29	46.25	11.57	1.77
Patna	97.10	66.77	None	None	11.54	15.99
Siliguri	90.07	46.32	None	None	5.50	4.80

Important Points for Discussion

- Short-Term Effects vs. Long-Term Trends: Lockdown policies had short-term changes in the atmosphere that emphasize the need for sustained emission reductions in order to enable ozone recovery as well as mitigate climate.
- Stratospheric Ozone Trends: Little direct impact of lockdowns on the concentration of stratospheric ozone because changes in ozone-depleting substances (ODS) are slow. Changes in atmospheric circulation patterns, including compromised polar vortexes, were reported during this time and attributed to natural variability [17].

Gaps In Literature

- Regional Disparities in Observations: Variations in ozone trends in developed vs. developing countries because of varying pollution control strategies and source emissions [18].

- Long-Term Monitoring and Integration of Data: Creating integrated datasets from ground-based, satellite, and model-based observations to quantify the entire extent of lockdown-related changes.
- Integrating Emerging Technologies: Utilizing machine learning and sophisticated simulation capabilities to study intricate chemical interactions and forecast future trends under different emission scenarios.
- Shortfalls in Integration with Climate Models: Limited utilization of integrated climate and chemical transport models to estimate long-term impacts of the lockdown on ozone recovery.

Conclusion

The lockdowns due to COVID-19 gave us a chance to analyze how human activity affects the ozone layer in a better way. This review provides information that, during the period of reduced air pollution, there was an increase in tropospheric ozone levels in urban areas, which is evidenced by improved satellite and ground-based data. It also notes, however, that there were no changes observed in the stratospheric ozone layer, which points towards the intricate dynamics that govern ozone distribution.

Also, the period highlighted the need to have ecological regulations focused on the environment and their capacity to positively contribute to climate policies. Interestingly, useful insights provided by this review come with gaps as well. The effect of ozone over long periods remains unexplored. There is no data pertaining to rural areas, and changes to temperature and stratospheric movements were ignored. The formulation of stronger policies can be achieved by looking at what role controlling emissions during lockdowns can have.

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