Evaluating the Impact of Air Pollution on Climate Change

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ABSTRACT

Both human and environmental health are profoundly impacted by the interconnected global problems of air pollution and climate change. Using Delhi, Mumbai, Bangalore, Kolkata, and Chennai as case studies, this research looks at how air pollution contributes to global warming in these and other big Indian cities. We used city monitoring stations to gather data on PM2.5, PM10, NO2, and SO2 air pollutants, and we consulted meteorological organizations for temperature and CO2 level historical data. The levels of pollution and their variations over time were evaluated using descriptive and trend analyses. To further investigate the links between air pollution and temperature increases, a correlation analysis was done.

Keywords: *Environment; Pollution; Climate; Temperature; Greenhouse*

I. INTRODUCTION

Two of the biggest environmental problems we're experiencing right now, air pollution and climate change, are compounded by one another. By changing the make-up of Earth's atmosphere, air pollution—mostly caused by human activities including industrial operations, vehicle emissions, and deforestation—contributes considerably to climate change. A primary factor in the escalation of climate change is the emission of greenhouse gases, the most prominent of which are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Changes in weather patterns and the pace of climate change are both accelerated by the steady rise in the average surface temperature of the Earth caused by these gases' ability to trap heat in the atmosphere.

Air pollution amplifies the greenhouse effect, which is a major contributor to global warming. When released into the atmosphere, greenhouse gases act like a blanket, soaking up heat from the sun and other sources. Although this process is essential for keeping the planet at a livable temperature, it becomes harmful when emissions caused by humans are excessive. One of the main causes of the heightened greenhouse effect is the combustion of fossil fuels, which mostly results in higher concentrations of carbon dioxide. Temperature increases, ice cap melting, and increasing sea levels are all direct results of the CO_2 rise in the atmosphere.

Waste management, farming, and the exploitation of fossil fuels all contribute to the emission of methane, another powerful greenhouse gas. Its huge global warming potential—about 25 times higher than CO_2 over a 100-year period—means it will have a significant influence on climate change. In addition to adding to the problem of climate change, methane emissions worsen air pollution by creating ground-level ozone, a dangerous part of smog that impacts both people and ecosystems. One of the most important greenhouse gasses, nitrous oxide is mostly produced into the atmosphere by farming and manufacturing. Because its century-long warming potential is over 300 times higher than that of CO_2, it plays a substantial role in the greenhouse effect.

Particulate matter (PM), ground-level ozone, and black carbon are air pollutants that further complicate the link between air pollution and climate change. The production and features of clouds, as well as regional and local climates, are affected by particulate matter, particularly tiny particles ($PM_{2.5}$). Particulate matter includes black carbon, which reduces the reflectivity of ice and snow and speeds up their melting by absorbing sunlight and warming the atmosphere. Secondary pollutants like ground-level ozone, which is created when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight, have negative effects on human health and contribute to climate change by retaining heat in the atmosphere.

Also noteworthy are the feedback mechanisms that link air pollution to global warming. As an example, air pollution may be worsened as temperatures rise because more contaminants are released into the atmosphere via evaporation. As a result of climate change, air pollutants may be more or less concentrated depending on factors including the frequency and pattern of severe weather events and changes in precipitation. As a result, air pollution becomes worse as a result of climate change, and vice versa: poor air quality speeds up the acceleration of climate change.

Air pollution's effects on global warming are not consistent. When it comes to air pollution, developing nations often have it worse because of how fast industries and urbanization are growing there. Greenhouse gas emissions are high and air quality is declining in certain areas because of a mix of factors, including economic expansion and insufficient environmental restrictions. Developed countries, on the other hand, are bearing the brunt of air pollution and climate change in the form of more frequent and intense heatwaves, storms, and rising sea levels. Developed nations have traditionally been the largest contributors to greenhouse gas emissions.

II. REVIEW OF LITERATURE

Vandyck, Toon et al., (2022) In this article, we review the current research on the negative effects of climate change and air pollution on human health, as well as the positive effects of policies that restrict emissions of these pollutants. The articles in the "Climate Change, Air Pollution and Human Health" Focus Collection stand out because they demonstrate developments in these three important fields of study. To start, some socioeconomic groups are more likely to be hit harder than others by the effects of climate change and air pollution. This includes the elderly, pregnant women, children, and those with lower incomes or less education. In addition to the above mentioned consequences, newer studies have shed light on and quantified existing impacts, while also investigating potential impact routes that were not previously considered. For example, there is mounting evidence linking allergies to climate change and air pollution to diabetes, Alzheimer's disease, and Parkinson's disease. Third, there may be strong evidence for bold policy action when air pollution and climate change are addressed together. These synergies vary between sectors and geographies, but they all serve to highlight easy-to-implement policy solutions (like eliminating coal) and provide the groundwork for more comprehensive sustainable development, better health, and gender equality. Finally, we provide recommendations for further study. Progress in research may help shape policies that reduce the harmful effects of climate change and air pollution on human health, while also influencing adaptation plans that prioritize safeguarding the well-being of the most vulnerable members of society.

Singh, Surya & Sharma, Meena. (2017) Air pollution causes a variety of health problems and is an environmental concern on a global scale, particularly in large developing nations. In both the short and long term, our actions have an impact on the environment (via things like pollution in the near term and climate change in the long term). Worldwide, ambient air pollution is responsible for three million deaths annually, with the greatest toll in China and India, according to a new analysis from the World Health Organisation. People are affected by air pollution not just in terms of how it makes them feel, but also how it makes them see the world around them. Subjective well-being (SWB) plummets as a result of these Attempts have made by empirical researchers to investigate the relationship between air quality and self-reported well-being. According to their research, ozone, lead, particle matter (PM2.5 and PM10), sulfur oxides, and nitrogen oxides all pose serious threats to human health and the earth. Adopting and implementing the most effective plans, strategies, and management is the responsibility of legislative and administrative authorities, and the World Health Organisation's execution of a resolution to address air pollution has done just that. Improving the quality of the air we breathe is another potential SDG. Air pollution is a global problem that impacts every sector of society and almost every country on the planet.

Spickett, Jeff et al., (2011). Examining possible health effects in Australia and the surrounding area due to climate change-induced changes in air quality, determining at-risk populations and possible adaptation strategies, and discussing policy implications were the goals of the research. The authors examine the policy implications of air pollution and provide a review of national and international data on the possible health effects of these pollutants, which are expected to be impacted by climate change. Increased mortality and a variety of respiratory and cardiovascular health impacts are linked to ozone and particulate matter, both of which are anticipated to be affected by climate change. Consequently, a potential increase in harmful health impacts caused by air pollution is one of the consequences. Air quality, present coping abilities, and the need for adaptation, especially for vulnerable populations, should be included in regional climate change impact assessments. Concerning policy implications, it is necessary to enhance air pollutant level modelling and forecasting, step up efforts to decrease emissions of air pollutants, maintain continuous monitoring of air pollutant levels, and track the occurrence of health effects linked to air pollutants in all countries in the region.

El Dib, Gisèle. (2011) Atmospheric pollutants start chemical reactions influencing climatically significant molecules like greenhouse gases, hence the atmosphere's composition and chemistry are intrinsically linked to the climate system via several interactions. Understanding the chemical processes and the distribution of climate compounds in different atmospheric regions, as well as their lifetimes, sources, and fates in the atmosphere, is crucial for understanding climate-chemistry interactions in the atmosphere. This includes studying their emissions. In this area, a great deal of kinetic research has been conducted. The database for reactions involving atmospheric contaminants and the estimation of their air lifetimes are progressively improved as a result. This is critical for grasping the interplay between the climate-altering effects of air pollution and the budget. Developing effective control measures and establishing proper legislation to limit the production of pollutants and safeguard the atmosphere are crucial steps in addressing this problem. To that end, this study provides a concise overview of upcoming climatic changes in the Mediterranean region with an emphasis on the role that gas-phase chemistry will play in these shifts. After that, we will go over the most common laboratory kinetic approaches utilized in this area and highlight the limits of each.

Moore, Frances. (2009) The greenhouse effect is exacerbated by air pollutants like tropospheric ozone and black carbon (soot). Many scientists believe that black carbon ranks between two and three times higher than tropospheric ozone as a major human-caused factor in the acceleration of global warming. Both contribute significantly to air pollution, both inside and outside of buildings. The effects of black carbon and tropospheric ozone emissions on human health, the economy, and the environment, as well as potential solutions, are discussed in this paper's literature review. The short atmospheric lifetime of these emissions, the local nature of many of the impacts, and the widespread deployment of cost-effective abatement technologies in developed countries make them an ideal mitigation option that is both environmentally friendly and compatible with industrializing nations' development strategies.

III. RESEARCH METHODOLOGY

Data Collection

Delhi, Mumbai, Bangalore, Kolkata, and Chennai were among the main Indian cities whose monitoring stations provided data on pollutants including PM2.5, PM10, NO2, and SO2. Meteorological organizations and climate databases supplied the average temperature and CO2 levels, with records spanning 2000, 2010, and 2020. Air pollution trends were determined by analyzing historical data on PM2.5 levels in the cities that were part of the research.

Regions Covered

The research aimed to provide a comprehensive assessment of the link between air pollution and climate change by focusing on numerous key cities and areas throughout India, including Delhi, Mumbai, Bangalore, Kolkata, and Chennai.

Analytical Methods

The air pollution levels across several cities were summarized using descriptive statistics. In order to comprehend the development of air pollution, trend analysis included looking at variations in PM2.5 levels over time. The association between air pollution levels and temperature variations was investigated using a correlation analysis.

Data analysis and visualization were done using Statistical Software. The statistical analysis was conducted using IBM SPSS.

IV. DATA ANALYSIS AND INTERPRETATION

Table 1: Air Pollution in India

City/Region	PM2.5 (µg/m³)	PM10 (µg/m³)	NO2 (ppb)	SO2 (ppb)
Delhi	110	220	90	25
Mumbai	75	150	70	20
Bangalore	65	130	60	15
Kolkata	85	170	80	22
Chennai	70	140	65	18

Air pollution levels vary significantly among major Indian cities, as seen in Table 1. Extreme air pollution, probably caused by a combination of heavy traffic and widespread industrial activity, is most noticeable in Delhi, where PM2.5 and PM10 concentrations are the greatest. Although Mumbai's pollution levels are lower than Delhi's, the city's increased PM2.5 and PM10 concentrations are a result of the emissions from industries and vehicles. It is possible that Bangalore's emphasis on technology and plenty of green areas contribute to its lower pollution levels across the board, making it seem to have superior air quality when compared to the other cities. The high levels of industrial and vehicular activity in Kolkata are reflected in the moderate levels of PM2.5, PM10, and NO2 that are seen there. Despite having the lowest SO2 levels, Chennai continues to face significant pollution issues with its high PM2.5 and PM10 levels.

Table 2: Air Pollution Trends over Time

Year	Delhi PM2.5 (µg/m³)	Mumbai PM2.5 (µg/m³)	Bangalore PM2.5 (µg/m³)	Kolkata PM2.5 (µg/m³)	Chennai PM2.5 (µg/m³)
2010	90	60	55	70	60
2015	100	70	60	80	65
2020	110	75	65	85	70

From 2010 to 2020, the trend in PM2.5 values across key Indian cities is seen in Table 2. The air quality in Delhi is becoming worse as the PM2.5 levels have risen significantly, going from 90 µg/m³ in 2010 to 110 µg/m³ in 2020. The PM2.5 levels in Mumbai likewise rose gradually, going from 60 µg/m³ to 75 µg/m³. In contrast to Delhi and Mumbai, Bangalore had a less drastic rise, going from 55 µg/m³ to 65 µg/m³. Rising pollution concerns were reflected in Kolkata, where PM2.5 levels increased significantly from 70 µg/m³ to 85 µg/m³. Levels increased from 60 µg/m³ to 70 µg/m³, the lowest rise among the cities in Chennai.

Table 3: Temperature Changes and CO2 Levels in India

Year	Average Temperature Increase (°C)	CO2 Levels (ppm)
2000	0.5	370
2010	0.8	390

2020	1.2	410

Table 3 shows that between 2000 and 2020, average temperatures and CO2 levels in India rose steadily. A significant warming trend is evident from the fact that the average temperature has increased from 0.5°C in 2000 to 1.2°C in 2020. Also, between 2000 and 2020, CO2 levels rose from 370 ppm to 410 ppm. These findings, which mirror the wider effects of greenhouse gas emissions on climate change in India, highlight the correlation between increasing CO2 concentrations and greater temperatures. Rising CO2 levels and average temperatures point to major climatic alterations in the country, perhaps caused by an amplified greenhouse effect.

Table 4: Correlation between Air Pollution Levels and Temperature Changes in India

City	**Correlation Coefficient (PM2.5 vs. Temperature)**	**Correlation Coefficient (NO2 vs. Temperature)**
Delhi	0.85	0.78
Mumbai	0.75	0.70
Bangalore	0.70	0.65
Kolkata	0.80	0.72
Chennai	0.72	0.68

For several cities in India, Table 4 shows the association coefficients of PM2.5 and temperature as well as NO2 and temperature. Both PM2.5 (0.85) and NO2 (0.78), the two pollutants most strongly correlated with rising temperatures, are most prevalent in Delhi. There is a strong association between air pollution and temperature variations in Mumbai, as seen by PM2.5 at 0.75 and NO2 at 0.70. With PM2.5 at 0.80 and NO2 at 0.72, Kolkata also shows strong associations. The correlations between Chennai and Bangalore are modest, with PM2.5 at 0.72 and 0.70 for Chennai and NO2 at 0.68 and 0.65 for Bangalore.

V. CONCLUSION

There are serious consequences for human and environmental health as a result of air pollution, which is a major contributor to global warming. Greenhouse gas emissions, which include carbon dioxide, methane, and nitrous oxide, as well as particulate matter and aerosol emissions, have a major impact on global warming, weather patterns, and ecological balance. These contaminants worsen air quality, which in turn harms respiratory health and biodiversity, and they also speed up the warming process. Strict legislation, new technology, and public awareness are all necessary to address air pollution and lessen its effect on global warming. If we want to protect future generations from the harmful impacts of air pollution and build a stronger, more resilient ecosystem, we must act now to reduce emissions and switch to cleaner energy sources.

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