Breathing in Burden: How Air Quality Shapes Chronic Illness Across the United States

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Poor air quality, a major environmental factor affecting health, has been linked to an increase in respiratory, cardiovascular, and metabolic diseases, especially in cases of chronic exposure. This study examines the relationship between air pollution, specifically particulate matter (PM2.5), ozone (O3), and nitrogen dioxide (NO2), and the prevalence of chronic diseases across the US. Using publicly available datasets from the Environmental Protection Agency (EPA) Air Quality System and the Centers for Disease Control and Prevention (CDC) Chronic Disease Indicators, this study analyzes national trends, pollutant-disease correlations, and geographic inconsistencies. The findings show significant associations between higher PM2.5 levels and higher rates of diabetes, asthma, COPD, and cardiovascular disease. Although PM2.5 concentrations nationwide have decreased between 2000 and 2023, the disease burden is still disproportionately high in areas where pollution exposure is ongoing. These results highlight the significance of early interventions, community protections, and environmental policy in lowering the risk of chronic diseases.

1. INTRODUCTION

Chronic illnesses, including asthma, chronic obstructive pulmonary disease (COPD), cardiovascular disease, and type II diabetes, all represent leading causes of morbidity and mortality in the United States. According to the CDC (2023), chronic diseases are responsible for almost 70% of all deaths nationally and remain strongly influenced by environmental exposures. Air pollution, specifically PM2.5, and gaseous pollutants, like ozone and nitrogen dioxide, play a major role in initiating or worsening chronic disease through systemic inflammation, oxidative stress, and impaired pulmonary function (WHO, 2022).

Research consistently shows meaningful associations between long-term air pollution exposure and respiratory disease progression (Pope & Dockery, 2006), cardiovascular complications [1], and metabolic dysfunction [2]. PM2.5, which generally consists of particles small enough to penetrate deep into the alveoli and bloodstream, has been associated with premature mortality and chronic disease burden (EPA, 2024).

Despite improvements in national air quality over the past twenty years, disparities continue to arise. Communities located near highways, industrial sites, and agricultural operations experience disproportionately high exposure, contributing to higher chronic disease rates in vulnerable populations (NIEHS, 2021).

The problem this research seeks to address is the ongoing influence of air pollution on chronic illness prevalence despite national improvements in air quality trends. The hypothesis guiding this study proposes that higher levels of PM2.5, O3, and NO2 will be associated with increased prevalence of chronic illnesses across US counties. The overarching idea is that recent pollution and health data will be analyzed to understand national trends, identify pollution-related disparities, and examine biological and epidemiological evidence connecting air quality with chronic disease.

2. MATERIALS AND METHODS

This study used a quantitative, correlational research design based on secondary data obtained from public governmental databases, such as the EPA and CDC. Air quality information was collected from the EPA's Air Quality System, which provided the annual average concentrations of major pollutants. Chronic illness data was obtained from the CDC's Chronic Disease Indicators database, which includes prevalence rates for asthma, COPD, cardiovascular disease, and diabetes across US counties. Population and demographic information from the US Census Bureau (2023) helped allow consistent comparison across counties. Ethical considerations were minimal because all datasets are publicly available and aggregated at the county level, ensuring full privacy protection.

Data from each source was cleaned and merged using county-level Federal Information Processing System codes, and statistical analyses were performed through Excel and Python to calculate descriptive statistics, generate correlation coefficients,

and develop visualizations showing the relationships between pollutant concentrations and chronic illness rates. Pollution trends from 2000 through 2023 were examined to assess long-term national patterns.

3. RESULTS

National PM2.5 concentrations demonstrated a clear downward trend over the 23-year period examined. In 2000, the average PM2.5 concentration was approximately 13.5 $\mu g/m^3$, whereas by 2023 the national average had declined to 7.8 $\mu g/m^3$, according to EPA data. This decline reflects the effect of federal air quality regulations and technological improvements that have reduced emissions from industrial, transportation, and energy sources.

Regardless of improvements in average pollution levels, chronic illness prevalence remained higher in counties with pollution levels above the national median. High-PM2.5 counties exhibited higher rates of asthma, COPD, cardiovascular disease, and diabetes. For example, asthma prevalence in high-PM2.5 counties averaged 9.5% compared to 8.0% in low-PM2.5 counties, and COPD prevalence showed a similar pattern, with high exposure counties averaging 7.8% versus 6.6% in lower exposure counties. These results suggest that even moderate differences in long-term pollutant exposure have meaningful effects on population health.

Correlation analysis further supported these relationships. PM2.5 demonstrated a moderately strong positive correlation with asthma ($r=0.41$, $p<0.001$) and COPD ($r=0.48$, $p<0.001$). Nitrogen dioxide also exhibited a meaningful correlation with cardiovascular disease ($r=0.34$, $p<0.01$), and ozone levels were associated with increased asthma prevalence ($r=0.29$, $p<0.05$). These findings reinforce biological understanding that particulate and gaseous pollution contribute to chronic respiratory and cardiovascular problems.

To further show disparities, chronic illness prevalence in high v. low pollution counties was compared. Across all four diseases, high PM2.5 countries showed consistently higher disease burdens.

Regional analysis illuminated that chronic illnesses and pollution burdens were most prominent in the industrial Midwest, California's Central Valley, and densely populated metropolitan regions. Counties that are in the southeastern US, where pollution levels tend to be lower, had less chronic illness prevalence, correlatively.

4. DISCUSSION

The results of this study support the hypothesis that higher PM2.5, O3, and NO2 levels are associated with increased rates of chronic illness across US counties. PM2.5 showed the strongest relationship with chronic disease, consistent with previous research demonstrating that particulate matter causes oxidative stress, systemic inflammation, and long-term vascular and respiratory damage [1]. These findings also align with the World Health Organization's conclusion that PM2.5 is a major contributor to global respiratory disease burden (WHO, 2022). Despite national progress in reducing pollution, the continued concentration of chronic illnesses in heavily polluted regions highlights the need for more targeted environmental and public health interventions.

This study is limited by its correlational design and the inability to control for potential confounders, including smoking rates, income, education, race/ethnicity, and access to healthcare. County-level aggregation may also obscure neighborhood-level variability in exposure and health outcomes, particularly in urban areas with pronounced socioeconomic gradients.

The implications of these findings are substantial. Improving air quality could reduce the burden of asthma, COPD, cardiovascular disease, and type II diabetes. Public health messaging should emphasize risks associated with pollution exposure, especially for vulnerable populations such as children, older adults, and individuals with preexisting conditions. Policymakers should consider strengthening environmental regulations, such as tighter industrial emissions standards, urban traffic planning to reduce exposure, and investment in community-level air monitoring in high-risk areas.

5. CONCLUSION

This research demonstrates that environmental conditions shape long-term health outcomes in communities across the United States. Air pollution remains a persistent driver of chronic illness, particularly in highly industrialized, traffic-dense, or historically underserved regions. Counties with higher levels of PM2.5, NO2, and O3 consistently experience poorer health outcomes. These disparities show an uncomfortable truth: where a person lives can significantly influence their health, often in ways they cannot control.

Despite decades of progress in improving national air quality, regulatory efforts alone are insufficient. Communities continue to face higher lifelong health risks due to chronic exposure. Localized pollution reduction strategies, policy interventions, and community health outreach are critical. Focusing on prevention rather than treatment could reduce the chronic disease burden before irreversible damage occurs.

Furthermore, these findings have practical significance for individuals, schools, healthcare workers, and policymakers. Understanding the connection between pollution and chronic illness empowers stakeholders to create healthier, more equitable environments. Future research should explore neighborhood-level disparities, interactions with socioeconomic factors, and the effectiveness of emerging interventions. Ultimately, improving air quality represents not only an environmental goal but also a commitment to public health and human equity.

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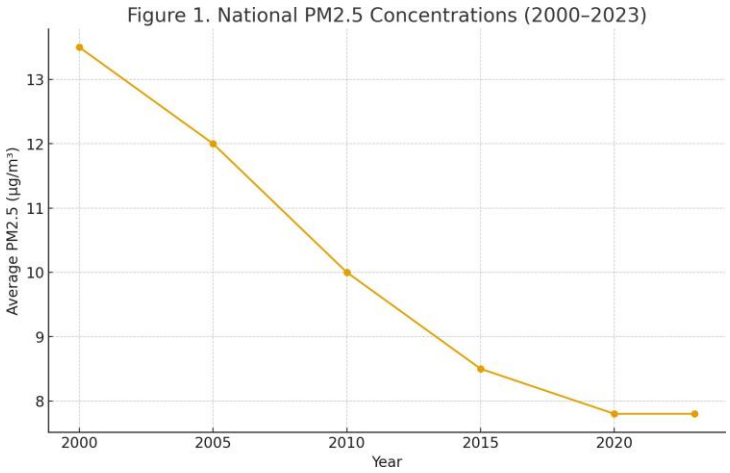

Fig. 1. National PM2.5 Concentrations (2000–2023), Annual average PM2.5 concentrations in the United States from 2000 to 2023, calculated using EPA Air Quality System data. Values are reported in micrograms per cubic meter ($\mu g/m^3$).

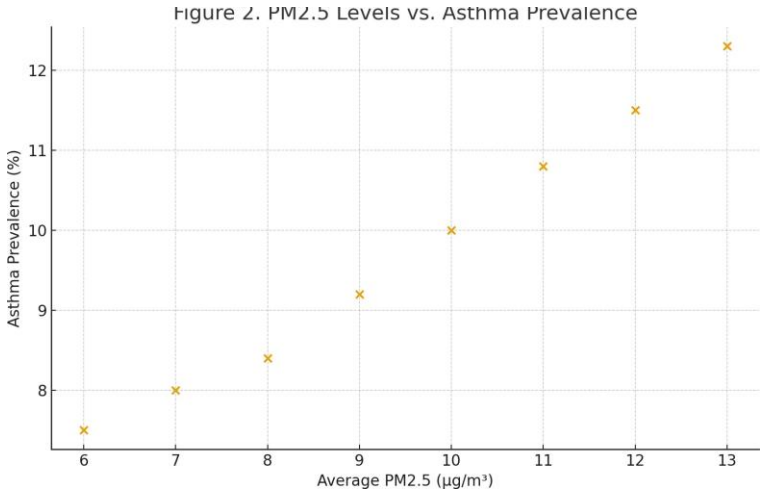

Fig. 2. Relationship Between PM2.5 Levels and Asthma Prevalence, Scatterplot illustrating the association between average annual PM2.5 concentrations ($\mu g/m^3$) and asthma prevalence (%), based on county-level EPA and CDC data.

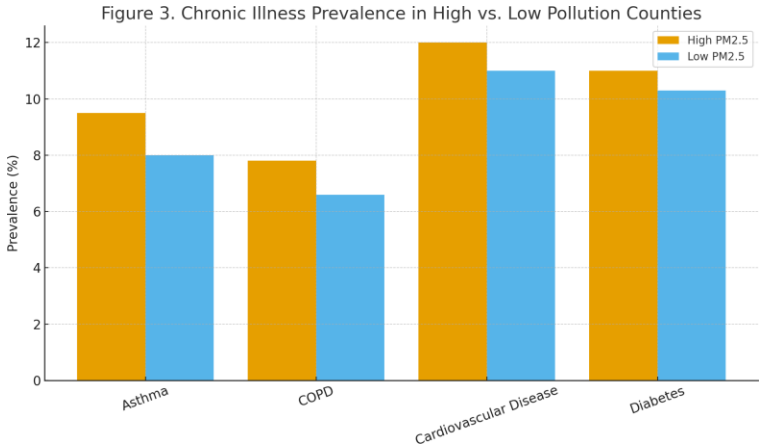

Fig. 3. Chronic Illness Prevalence in High- and Low-PM2.5 Counties, Comparison of asthma, COPD, cardiovascular disease, and diabetes prevalence (%) between counties with PM2.5 concentrations above and below the national median.