Air Pollution and Health Inequality in Low-Income Communities
: A Spatial and Policy Analysis

Air pollution significantly impacts low-income communities, amplifying existing health inequalities and contributing to higher rates of respiratory diseases. This study investigates the relationship between air pollution exposure and adverse health outcomes, integrating environmental, health, and socioeconomic data to provide a comprehensive analysis of environmental injustice.

The study uses high-resolution air quality data from the EPA's Air Quality System (AQS), NASA's MODIS and Sentinel-5P satellites, and OpenAQ's monitoring network to assess concentrations of PM2.5, NO_2, O_3, and other pollutants at the local level. Public health data from the CDC's National Environmental Public Health Tracking Network, National Health Interview Survey (NHIS), and Medicaid/Medicare records provide insights into disease prevalence and healthcare access. Socioeconomic data from the American Community Survey (ACS), Bureau of Labor Statistics (BLS), and HUD offer context on income levels, poverty rates, and healthcare infrastructure. Additionally, environmental justice indicators from the EPA's EJSCREEN and CalEnviroScreen help assess disparities in environmental exposure.

Methodologically, spatial econometric models (geographically weighted regression, spatial autocorrelation) are applied to map pollution exposure disparities across socio-economic groups. Multivariate regression analyses quantify the relationship between air pollution and health outcomes, controlling for socioeconomic factors such as income, education, and healthcare access. A difference-in-differences (DiD) approach is used to evaluate the effects of air quality regulations on public health outcomes over time, with a particular focus on vulnerable communities. Furthermore, machine learning models, including Random Forest and XGBoost, identify high-risk areas and key predictors of pollution-driven health disparities.

Preliminary findings indicate that communities exposed to PM2.5 levels exceeding the WHO threshold of 10 $\mu g/m^3$ experience up to a 20% higher incidence of respiratory diseases, particularly in regions with limited healthcare access. These findings emphasize the need for targeted interventions, such as stricter emissions regulations, expanded public transportation infrastructure, and community-based healthcare programs, including mobile clinics and targeted health screenings. Moreover, the equitable distribution of environmental resources and investments in clean energy transitions are vital for mitigating long-term health risks and fostering sustainability.

While the study provides empirical insights, some limitations must be acknowledged. Measurement errors from satellite-based air quality data can affect the accuracy of pollution estimates, particularly in regions with limited ground-based monitoring. Furthermore, this study does not account for other environmental stressors, such as noise pollution and extreme temperature variations, which also influence health outcomes. Future research should explore these additional factors and examine policy effectiveness in an international context, as environmental health disparities may vary significantly across countries and regions. Expanding the analysis to include other stressors will provide a more comprehensive understanding of how multiple environmental factors interact to influence health disparities.

Keywords: Air pollution, health inequality, environmental justice, spatial analysis, public health policy, machine learning