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Spatio-Temporal Analysis of the Roadside Transportation-Related Air Quality (StarTraq 2022): Data-Driven Exposure Analysis by Transportation Modes

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Introduction

Californians in the San Joaquin Valley bear a disproportionate burden of heavy traffic, with vehicle exhaust being the primary source of air pollution that impacts human health. Transportation-related air pollution has severely impacted the low-income and minority communities near truck depots, rail yards, and highways. Addressing air quality issues is crucial for mitigating environmental and public health impacts and ensuring equity in distributing benefits and burdens. Previous StarTraq projects have examined transportation-related particle pollution across various modes of transportation and spatial characteristics, revealing significantly elevated levels of pollutants near roadways. Particulate matter (PM), a major component of air pollution, poses significant health risks globally and contributes to millions of deaths annually. This study focuses on Fresno, California, investigating how meteorological factors affect PM levels, such as temperature, humidity, wind speed, and direction. It aims to collect mobile air quality data to analyze spatial variations of transportation-related $PM_{2.5}$ and assess the inhalation risk in different scenarios. The study aims to provide a unique understanding of the PM-meteorology relationship in Fresno, distinct from region-specific models. Research goals include exploring linear and non-linear relationships between PM and meteorological factors, assessing their statistical significance, and examining seasonal effects by distinguishing between "hot" and "cool" seasons in Fresno.

Study Methods

The regression method has been extensively employed to investigate the relationship between variables. Although various regression methods exist, we primarily explore the linear and non-linear relationships between PM and meteorological factors. For this purpose, multiple linear regression (MLR) and generalized additive models (GAMs) have been utilized. MLR is commonly used in diverse applications due to its simple model interpretations resulting from its linear model structure. However, as many variables exhibit non-linear relationships, GAM is employed to examine these non-linear associations.

Findings

Our key findings are as follows:

1. PM_{10} Analysis using MLR and GAM: During the whole season, humidity and wind speed are significant factors for PM_{10}. During the hot season, temperature, humidity, wind speed, and wind direction are all significant. During the cool season, humidity and wind speed are significant factors.
2. $PM_{2.5}$ Analysis using MLR: Wind speed is the only significant factor for $PM_{2.5}$ throughout the season. During the hot season, temperature and wind speed are both significant. During the cool season, temperature and wind speed are significant factors.
3. $PM_{2.5}$ Analysis using GAM: During the whole season, temperature, humidity, and wind speed are the significant factors for $PM_{2.5}$. During the hot season, temperature and wind speed are both significant. During the cool season, wind speed is the only significant factor.
4. Regional air quality $PM_{2.5}$ measured at Fresno station and meteorological conditions were closely related to the on-road particulate matter concentrations. In most cases, $PM_{2.5}$ on the highways was higher than $PM_{2.5}$ on the local roadways. On-road transportation-related particle pollutants measured in the San Joaquin Valley were significantly higher than those measured in the Bay Area.
5. The average daily dose (ADD) of transportation-related $PM_{2.5}$ estimation based on a 2-hour commute and an 8-hour trip scenario estimated that the children's average daily dose of $PM_{2.5}$ is significantly higher than the ADDs of adults' age groups.
6. The in-vehicle average daily doses were significantly lower than the on-road ADD. Estimating inhalable exposure to $PM_{2.5}$ on the road can be applied to people who work or live in close proximity to heavy traffic.

Our results also indicate that regardless of PM_{10} or $PM_{2.5}$, temperature was a significant factor during the hot season. The relationship between PM and temperature has always been positive in both models.

Policy/Practice Recommendations

- Enhance air quality monitoring: Establish a robust air quality monitoring network in Fresno that includes measurements of PM concentrations and meteorological parameters such as temperature, humidity, wind speed, and wind direction. This will provide real-time data to track pollution levels and understand the relationship between PM and meteorological factors.
- Develop seasonal pollution control strategies: Recognizing the seasonal variations in PM composition and meteorological factors, design tailored pollution control strategies for the "hot" and "cool" seasons. During the hot season, focus on mitigating the impact of temperature, humidity, wind speed, and wind direction through heat mitigation strategies, controlling dust sources, and optimizing traffic management. In the cool season, prioritize addressing humidity and wind speed by managing indoor heating systems, promoting energy-efficient practices, and reducing emissions from combustion sources.
- Promoting electric vehicles reduces the regional transportation-related particulate matter generated by internal combustion engines.

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To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2220

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