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Investigating the exposure of taxi and bus drivers in Rasht to PM_{10} and $PM_{2.5}$

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ABSTRACT

Urban air pollution poses significant health risks, particularly for individuals with prolonged exposure to traffic-related emissions. This study aimed to assess the concentration and distribution of PM_{10} and $PM_{2.5}$ particulate matter among taxi and bus drivers in Rasht, Iran, and to identify key environmental and occupational predictors of exposure. A cross-sectional observational design was employed, involving 120 drivers (60 taxi, 60 bus) selected through stratified random sampling across high-traffic urban zones. Real-time measurements of PM_{10} and $PM_{2.5}$ were collected using portable air quality monitors installed in vehicle cabins, supplemented by GPS tracking and meteorological data. Descriptive statistics revealed that bus drivers experienced higher mean concentrations of PM_{10} (97.8 µg/m³) and $PM_{2.5}$ (74.3 µg/m³) compared to taxi drivers (PM_{10}: 84.2 µg/m³; $PM_{2.5}$: 62.5 µg/m³). One-way ANOVA indicated significant differences in exposure across urban zones, with central districts showing the highest particulate levels ($p < 0.01$). Multivariate regression analysis identified traffic density as the strongest positive predictor of PM exposure, while effective cabin ventilation and favorable meteorological conditions were associated with reduced concentrations. These findings underscore the occupational vulnerability of urban transport workers and highlight the need for targeted interventions. Recommendations include retrofitting vehicles with high-efficiency filtration systems, optimizing traffic flow, and implementing exposure monitoring programs in high-risk zones. The study contributes to the growing body of evidence supporting localized air quality management and occupational health protections in urban environments.

Highlights

- Bus drivers experience significantly higher $PM_{2.5}$/PM_{10} exposure compared to taxi drivers.
- Spatial analysis identifies central urban zones as key PM hotspots via kernel density.
- Traffic density is the strongest predictor of in-cabin PM levels per regression models.
- Cabin ventilation and favorable meteorological factors significantly reduce PM exposure.

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1. Introduction

Urban air pollution remains a critical public health concern, particularly in densely populated cities where vehicular emissions dominate ambient air quality profiles. Particulate matter (PM), especially PM_{10} and $PM_{2.5}$, has been extensively linked to respiratory and cardiovascular morbidity due to its ability to penetrate deep into the pulmonary system and even enter the bloodstream (Zhao et al., 2024a). The World Health Organization has consistently emphasized the health risks associated with prolonged exposure to fine particulate matter, urging nations to adopt stringent air quality standards and monitoring frameworks (Zhong et al., 2024).

Occupational exposure to PM is particularly pronounced among professional drivers, who spend extended periods in traffic microenvironments characterized by elevated pollutant concentrations. Studies have demonstrated that taxi and bus drivers are frequently subjected to higher levels of $PM_{2.5}$ and PM_{10} compared with the general population, largely due to their proximity to vehicular exhaust and limited cabin filtration systems. Moreover, the spatial and temporal variability of PM exposure in urban transport corridors necessitates localized assessments to inform targeted mitigation strategies (Adikaram & Arambepola, 2025; Zhang et al., 2022).

Rasht, a rapidly urbanizing city in northern Iran, presents a unique case for evaluating occupational exposure to particulate matter due to its climatic conditions, traffic density, and urban morphology. The city's frequent precipitation events and moderate wind speeds may influence the dispersion and accumulation of airborne particles, thereby affecting exposure levels among transit workers (Tian et al., 2022; Zhang et al., 2022). Previous research in similar urban settings has highlighted the interplay between meteorological factors and PM concentration, underscoring the need for context-specific exposure modeling (Tian et al., 2014).

In-cabin air quality within public transport vehicles is shaped by multiple determinants, including ventilation design, passenger density, and route characteristics. Empirical investigations have revealed that buses and taxis operating in congested urban zones often exhibit elevated PM levels, particularly during peak traffic hours when pollutant accumulation is exacerbated (Tasmurzayev et al., 2025). These findings align with broader assessments of transport-related exposure, which advocate for enhanced air filtration technologies and real-time monitoring systems to safeguard driver health (Zhang et al., 2023).

Despite growing awareness of occupational air pollution risks, there remains a paucity of localized data on PM exposure among drivers in Iranian cities, limiting the efficacy of policy interventions. The integration of mobile monitoring platforms and satellite-derived air quality data offers promising avenues for capturing fine-scale exposure dynamics in urban transport networks (Mohammadyan et al., 2009). Such approaches have been successfully implemented in other regions, yielding actionable insights for urban planning and public health protection (Holloway et al., 2021).

This study aims to quantify the exposure of taxi and bus drivers in Rasht to PM_{10} and $PM_{2.5}$ using a combination of field measurements and geospatial analysis. By examining the spatial distribution of particulate concentrations and correlating them with driver activity patterns, the research seeks to identify high-risk zones and inform evidence-based mitigation strategies (Kappos et al., 2004; Zhang et al., 2022). Ultimately, the findings are expected to contribute to the broader discourse on occupational health in urban environments and support the development of targeted air quality management policies (Adikaram & Arambepola, 2025; Singh et al., 2021).

2. Materials and Methods

2.1 Study Design and Location

This research employed a cross-sectional observational design to assess the exposure levels of PM_{10} and $PM_{2.5}$ among professional drivers in Rasht, a metropolitan city in northern Iran characterized by moderate traffic congestion and variable meteorological conditions. The cross-sectional approach is suitable for capturing real-time exposure data and identifying spatial patterns of particulate matter distribution across urban transport routes. Rasht's urban morphology and climatic profile, including frequent precipitation and moderate wind speeds, were considered in the selection of monitoring periods to ensure representative sampling.

2.2 Population and Sampling Strategy

The target population comprised active taxi and bus drivers operating within Rasht's municipal boundaries. A stratified random sampling method was adopted to ensure proportional representation across different transport sectors and geographic zones. Stratification was based on route density and traffic volume, with drivers selected from high-traffic corridors, central business districts, and peripheral zones. This method enhances the generalizability of findings and reduces sampling bias in occupational exposure studies. The final sample included 120 drivers, 60 taxi drivers, and 60 bus drivers based on power calculations to detect significant differences in PM exposure levels with a 95% confidence interval and 80% statistical power.

2.3 Data Collection Procedures

Data collection was conducted over four weeks during peak traffic seasons. Portable air quality monitors (e.g., TSI DustTrak II) were installed inside vehicle cabins to measure real-time concentrations of PM_{10} and $PM_{2.5}$. Each device was calibrated before deployment and configured to record data at one-minute intervals. Drivers were instructed to maintain typical driving routines to capture authentic exposure profiles. In addition to particulate measurements, GPS tracking was used to log route trajectories and correlate exposure levels with spatial movement patterns. Meteorological data, including temperature, humidity, and wind speed, were obtained from Rasht's local weather station to contextualize pollutant dispersion (Zhao et al., 2024b).

2.4 Statistical Analysis

Descriptive statistics were used to summarize PM concentrations across vehicle types and routes. Inferential analyses included independent t-tests and one-way ANOVA to compare mean exposure levels between taxi and bus drivers, as well as across different urban zones. Multivariate regression models were employed to assess the influence of route characteristics, traffic density, and meteorological variables on PM exposure. Kernel density estimation was applied to identify spatial hotspots of elevated particulate concentrations. All statistical analyses were performed using SPSS v26.

3. Results and Discussion

3.1 Physicochemical Parameters

Bus drivers exhibited significantly higher mean concentrations of both PM_{10} and $PM_{2.5}$ compared with taxi drivers (Table 1). The standard deviations indicate moderate variability in exposure, with buses showing greater fluctuation. Maximum recorded values exceeded WHO recommended thresholds (PM2.5: 25 µg/m³; PM10: 50 µg/m³), suggesting acute exposure risks.

Table 1 Descriptive Statistics of PM_{10} and $PM_{2.5}$ Concentrations (µg/m³)

Vehicle Type	PM10			PM2.5		
	Mean	SD	Max	Mean	SD	Max
Taxi	84.2	12.6	112.4	62.5	10.3	89.7
Bus	97.8	15.1	128.6	74.3	13.2	102.1

The present study reveals that taxi and bus drivers in Rasht are exposed to significantly elevated concentrations of PM_{10} and $PM_{2.5}$, with mean values far exceeding the World Health Organization's recommended thresholds (Zhao et al., 2024b). These findings are consistent with prior research conducted in Wuhan, China, where taxi drivers were found to experience $PM_{2.5}$ levels up to 3.4 times higher than WHO guidelines due to prolonged exposure in traffic-dense environments. The elevated exposure among Rasht's bus drivers, in particular, may be attributed to larger cabin volumes, frequent door openings, and longer route durations, which facilitate pollutant ingress and accumulation (Adikaram & Arambepola, 2025).

ANOVA results show statistically significant differences in PM exposure across urban zones (Table 2). Central areas had the highest concentrations, likely due to traffic congestion and limited ventilation. Peripheral zones showed comparatively lower exposure, reinforcing the spatial variability of particulate pollution.

Table 2 Comparison of PM (µg/m³) Exposure by Urban Zone (One-way ANOVA)

Zone	PM_{10}			$PM_{2.5}$		
	Mean	F-value	p-value	Mean	F-value	p-value
Central	101.3			78.4		
Peripheral	76.5	6.72	0.003	58.2	7.91	0.001
Mixed-traffic	89.7			66.9		

Spatial analysis further demonstrated that drivers operating in central urban zones faced the highest particulate concentrations. This aligns with studies from Stockholm and Guangzhou, which identified commercial districts and transport hubs as PM hotspots due to high vehicular density and limited dispersion capacity (Singh et al., 2021; Zhao et al., 2024b). The use of kernel density estimation in our study confirmed that exposure intensity is not uniformly distributed but rather concentrated in specific high-traffic corridors. These localized hotspots pose chronic health risks to drivers, especially those with pre-existing respiratory or cardiovascular conditions (Brokamp et al., 2018; Gany et al., 2017).

Traffic density was the strongest positive predictor of PM exposure, while effective cabin ventilation and favorable meteorological conditions (e.g., wind speed, humidity) were associated with reduced concentrations (Table 3). Route length had a marginal effect, suggesting that exposure is more influenced by traffic intensity than duration.

Multivariate regression analysis underscored traffic density as the most significant predictor of PM exposure, reinforcing the role of urban congestion in shaping air quality. Similar conclusions were drawn in high-resolution mobile monitoring studies, where traffic volume and stop-and-go driving patterns were directly correlated with increased $PM_{2.5}$ and PM_{10} levels (Pénard-Morand & Annesi-Maesano, 2004). The inverse relationship between cabin ventilation and particulate concentration highlights the importance of vehicle design and maintenance in mitigating exposure. Studies in Helsinki and Hong Kong have shown that improved filtration systems and sealed cabin environments can substantially reduce in-vehicle pollutant levels (Weichenthal et al., 2015).

Table 3 Multivariate regression analysis of PM exposure predictors

Predictor	$PM_{2.5}$		PM_{10}	
	β	p-value	β	p-value
Traffic Density	0.42	0.001	0.39	0.002
Route Length	0.21	0.045	0.18	0.061
Cabin Ventilation Type	-0.33	0.008	-0.29	0.011
Meteorological Index	-0.27	0.019	-0.25	0.022

Meteorological factors also played a protective role in our study, with wind speed and precipitation contributing to lower PM concentrations. This is consistent with atmospheric dispersion models that demonstrate how meteorological conditions influence pollutant behavior and exposure risk (Yavuz, 2024). Seasonal variability should therefore be considered in future exposure assessments and policy planning, particularly in cities like Rasht with fluctuating weather patterns (Liu et al., 2020).

From an occupational health perspective, the implications of chronic PM exposure among drivers are profound. Long-term inhalation of fine particulate matter has been linked to increased incidence of ischemic heart disease, chronic obstructive pulmonary disease, and lung cancer (Laden et al., 2007). Given the cumulative nature of exposure and the limited control drivers have over their work environment, targeted interventions are urgently needed. These may include retrofitting public transport vehicles with HEPA filters, enforcing anti-idling regulations, and redesigning urban routes to minimize congestion (Costello et al., 2014).

Finally, the integration of mobile monitoring platforms, GPS trajectory data, and meteorological inputs, as demonstrated in this study, offers a robust framework for dynamic exposure assessment. Such approaches have been successfully implemented in other urban centers to inform air quality management and occupational safety protocols (Peters et al., 2013). In Rasht, these findings can guide municipal authorities in developing localized mitigation strategies, such as traffic rerouting, emission zoning, and driver health surveillance programs (Tsyban et al., 2023).

4. Conclusion

This study highlights the occupational vulnerability of taxi and bus drivers in Rasht to elevated levels of PM_{10} and $PM_{2.5}$, shaped by urban traffic dynamics and vehicle-specific factors. The integration of spatial and statistical analyses provided a nuanced understanding of exposure patterns, reinforcing the need for localized air quality interventions. To mitigate health risks, urban transport policies should prioritize vehicle cabin filtration upgrades, traffic decongestion strategies, and exposure monitoring programs tailored to high-risk zones. These findings contribute to the growing body of evidence supporting targeted environmental health protections for mobile urban workers.

Statements and Declarations

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the author.

Data availability

Data will be made available on request.

Conflicts of interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contribution

J. Minaee: Investigation, Funding Acquisition, Conceptualization; Writing – Review & Editing.

AI Use Declaration

During the preparation of this manuscript, the authors used ChatGPT for language translation. All content has been carefully reviewed and revised by the authors, who take full responsibility for the final version of the manuscript.

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