Chapter 8

Conclusions

This chapter presents the key findings and contributions of the study. This chapter suggests policies to reduce pollutant exposures. The chapter also highlights the study's limitations and outlines areas for future research.

8.1 Background

The on-road PM exposure study was conducted in a Tier-II Indian city, Varanasi. The study was conducted on various routes of the city during 2022 for 8 months except the rainy season. The goal of the study was to model average, extreme and real-time PM concentrations using various meteorological and traffic factors. The following four objectives of the study were presented in separate chapters:

1. Compare PM Concentrations between the BHU campus and Varanasi city (Chapter 4)

2. Investigate factors that affect average on-road PM concentrations (Chapter 5)

3. Study extreme PM exposure at traffic intersections (Chapter 6)

4. Model the effect of traffic composition on commuters' exposure to PM (Chapter 7)

Key findings, policy implications and future scope of this work are presented next.

8.2 Key Findings

Chapter-wise conclusions are presented at the end of each chapter. The following are the main conclusions drawn from the investigation carried out to fulfill the study objectives:

1. The pollution in Varanasi city is significantly higher than the PM concentration inside the university campus.

2. Atmospheric temperature, relative humidity, season of the year and hours of the day were found to be good predictors in exposure modeling. Traffic count was also an important factor in predicting on-road particulate exposure concentration.

3. The on-road PM concentration can be estimated using data obtained from properly calibrated ambient monitoring stations.

4. Mixed effect linear regression modeled PM exposure more effectively than simple linear regression.

5. The Bayesian inference was suitable for modeling monthly return levels and predicting the probability of extreme pollution events.

8.3 Key Contributions

1. This study is the first of its kind to model the average, extreme, and real-time PM exposure concentrations of commuters in a densely populated Indian city.

2. Determining the exposure of a moving subject to exhaust and non-exhaust emissions from a heterogeneous and non-lane-based traffic fleet is challenging. This study aggregated and quantified the effect of both exhaust and non-exhaust emissions in the form of pollution exposure to commuters.

3. Only a single factor can't decide the commuters' exposure to pollutant concentration. The study reviewed the combined effect of multiple factors affecting commuters' exposure to PM. The combined effect of seasons with temperature and humidity and seasons with traffic congestion (PHT and OPHT) is very crucial in finding the effect of factors on exposure patterns.

4. This study employed both classical approaches (linear regression and mixed-effects models) and Bayesian approaches (Bayesian hierarchical models) to model commuters' exposure to PM. Most studies in the past were based on classical approaches. Therefore, some probability questions that can be directly answered by the Bayesian method were not explored.

8.4 Policy Implications

The study observed elevated PM exposure concentration across all routes and traffic intersections in Varanasi, India. These findings raise concerns about the environment and public health. Based on the literature reviews and findings of the study, the following suggestions are made for policymakers.

1. People spending a prolonged time at the intersection would be affected. The route with multiple intersections was identified to be the worst in terms of PM exposure. Commuters should avoid taking such routes.

2. The information can be proactively shared with the public, highlighting pollution hotspots. These hotspot maps can be updated with continuous mobile monitoring data so that commuters can take routes with lower pollution exposures.

3. About 6 – 7 million tourists visit Varanasi annually, leading to traffic congestion and increased pollutant concentrations. Based on the findings of the study, the probability

of occurrence of extreme PM exposure events is significantly higher in winter. Thus, policies such as parking management, low emission zones, traffic signal timing and pedestrian facilities should be devised to minimize extreme PM exposure, especially for tourists. In addition, public administration and urban planners may implement abatement measures to reduce pollutant concentration around traffic intersections.

4. Some of the abatement measures are better traffic management, emission standards, scrappage programs, intelligent transport systems, road dust cleaning, and awareness programs for commuters to use public transit, non-motorized vehicles, and electric vehicles (Sioshansi and Denholm, 2009; Smit et al., 2010).

8.5 Limitations and Future Scopes

A variety of factors influence a motorcyclist's exposure to PM. Capturing the effect of all factors in a single study is not always feasible. Future studies could incorporate parameters such as wind speed and direction, building heights and road layout, route topography and terrain, and more detailed traffic parameters such as traffic composition, counts, and density. Also, this study did not explore PM exposure during the night. However, the pollutant concentrations at night are reduced due to less traffic than during the day hours, and the consequent probability of PM exposure might be lower than during the day. The study explored the PM exposure for the open-mode (motorcycle) commuters. Future studies should carry out PM studies for closed modes. The PM data was collected using portable instruments mounted on a motorcycle. Although the spatial coverage was adequate and very cost-effective, the temporal coverage could be enhanced by integrating data from stationary sensors (or receptors) at various locations in the city.