

**IMPACT OF URBAN-RURAL INTERFACE AIR
POLLUTION ON AMBIENT AIR QUALITY: A CASE STUDY
IN THE DISTRICT OF SAHARANPUR**

GAURAV TOMAR



**CENTRE FOR RURAL DEVELOPMENT AND TECHNOLOGY
INDIAN INSTITUTE OF TECHNOLOGY DELHI
NOVEMBER 2023**

© INDIAN INSTITUTE OF TECHNOLOGY DELHI, NEW DELHI 2023
ALL RIGHTS RESERVED

**IMPACT OF URBAN-RURAL INTERFACE AIR POLLUTION
ON AMBIENT AIRQUALITY: A CASE STUDY IN THE
DISTRICT OF SAHARANPUR**

**by
Gaurav Tomar**

Center for Rural Development and Technology

*submitted
in fulfillment of requirements of degree of*

Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

NOVEMBER 2023

CERTIFICATE

This is to certify that the thesis entitled “**Impact of Urban-Rural Interface Air Pollution on Ambient Air Quality: A Case Study in The District of Saharanpur**”, being submitted by **Mr. Gaurav Tomar** to the Indian Institute of Technology Delhi for the award of “**Doctor of Philosophy**” is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis. To the best of our knowledge, the results contained in this thesis have not been submitted in part or full to any other university or institute for the award of any degree or diploma.

Dr. Vivek Kumar

Professor

Centre for Rural Development and Technology

Indian Institute of Technology Delhi

New Delhi-110016

ACKNOWLEDGEMENTS

As I complete my journey of a learning filled Ph.D. and shed light on my time at IIT Delhi, I find people without whom this journey would have been incomplete. With a lot of sincerity and gratitude, I would have to thank these people to acknowledge their support during this long journey. This voyage would have been impossible without God's will and blessings. Though its tinycreation, I thank God and owe my success to the Almighty.

I want to show my gratitude towards my supervisor, **Prof. Vivek Kumar**, his constant guidance and support ensured that this thesis is brought out without confusions and is getting completed in a streamlined manner. The work throughout and the completion, was easier due to your active participation and immense efforts. I would like to express my heartfelt gratitude to Dr. Ajay Singh Nagpure for his invaluable mentorship and unwavering support throughout my Ph.D. journey. His guidance has been instrumental in shaping my research and helping me navigate the technical complexities. Moreover, I pay my heartfelt gratitude for my Ph.D. research committee members: **Dr. Vijayaraghavan M Chariar, Dr. Mukesh Khare, and Dr. Virendra K. Vijay** for their advice to enhance the quality of my research work.

Further, I can never thank enough my colleagues for their tireless and passionate support for my work and personal life. All of you have been the part of my daily life and your contributions is massive, in completion of this thesis and my Ph.D. I pay my heartfelt gratitude to **Dr. Smita S. Kumar, Dr. Madan Kumar, Mr. Nitin Agarwal, Mr. Yash Jain, and Mr. Ritesh Kumar**. I would also like to acknowledge MHRD for providing financial assistance. I acknowledge the support of Centre for Rural Development and Technology, Energy and Environment Laboratory, High Performance Computing (HPC) at IITD for providing me necessary resources during this journey.

My friends, have been a strong support system through all the ups and downs I went through during this journey. I will be always grateful to my friends **Prabhat, Anjali, Mohit, Asit, Mitul, and Dharti** for the immense support. A Ph.D. life with some helpful friends makes it one of the most wonderful times of life. Furthermore, I will be always grateful to my sisters **Sarita Rathi, Neetu Malik and Garima** for supporting me during Ph.D. as well as in other life situations. Finally, I owe every bit of this accomplishment to my parents, **Mr. Rajveer Singh and Mrs. Munni Devi** for providing the opportunity to keep getting better and excel in life. I would also like to express my sincere gratitude to my parents-in-law **Mr. Satbeer Singh** and **Mrs. Mukesh Devi**, and brother-in-law **Ashwani Yadav** for their constant support

throughout this journey.

Last but not the least, I want to share this moment with my baby girl **Ameyaa** and my wife **Mrs. Pooja Yadav**, who has been a constant support emotionally as well as logistically during some of the tough times endured during this journey.

A handwritten signature in blue ink, appearing to read 'G. Tomar', with a horizontal line underneath.

Gaurav Tomar

ABSTRACT

Ambient air pollution levels in Indian regions have been breaching alarming levels regularly. These high air pollution levels lead to substantial human health impacts, which can further translate into loss of livelihood in the available workforce. Addressing the information gap on contribution of various infrastructure sectors to air pollution in smaller Indian cities and rural area, the current work carried out in an Indian district, Saharanpur, estimates high resolution $PM_{2.5}$ emission. The observations suggests that in urban areas of the region; transport, open waste burning, HH cooking fuel, and industries annually contribute 97 tonnes (5%), 368 tonnes (18%), 499 tonnes (24%), and 1121 tonnes (53%) to the total $PM_{2.5}$ emissions, respectively. In rural areas; transport, open waste burning, industries, agriculture residue burning and HH cooking fuel annually contributes 236 tonnes (2%), 1201 tonnes (11%), 1824 tonnes (16%), 3732 tonnes (33%), and 4349 tonnes (38%) to total $PM_{2.5}$ emissions, respectively. These contribution patterns and their high-resolution analysis is critical to finding sources of importance and planning microlevel activities based on individual sector's hotspots to mitigate air pollution and its impact. The results point towards priority for sectors like HH cooking fuel burning, industries, and agriculture residue burning in the region. However, some areas would also require stricter implementation in transportation and solid waste burning sectors, as they can prove to be a critical factor in deciding the air quality of a local hotspot.

Finally, with the help of dispersion modelling and health impact assessment using concentration response function, high resolution health impacts in the study domain are estimated. Estimation of health and livelihood impact on a finer scale is achieved to analyze the varying contribution to and exposure from air pollution in varying demographic and socioeconomic groups. Health and livelihood impact from ambient air pollution among populations in developing countries are disproportional. These disparities are often overlooked due to lack of information on micro-level emission data, especially in smaller cities and rural areas. Therefore, the current work also analyses the health impacts estimated based on the surface $PM_{2.5}$ concentration and suggest that the rate of premature deaths is 158 (95% CI: 122-163) and 143 (95% CI: 65-151) deaths per 1,00,000 people in urban and rural areas, respectively. 68% of the 6372 (95% CI: 3321-6987) annual premature deaths occurs in rural areas. Depicting higher contribution-exposure disparities among socioeconomic groups, the study observed that compared to their contribution to air pollution, low Socioeconomic Status (SES) groups in the region experience 6, 7, 7, 26, and 7% more premature deaths from $PM_{2.5}$ exposure for industries, household cooking fuel burning, open waste burning, and

transportation, respectively. Majority of Daily adjusted Life Years (DALYs) in the study domain are observed in economically weaker worker categories. Reduced income due to loss of these life years will significantly impact these groups due to their dependence on daily wages for basic life necessities.

Micro-level pollution mitigation policies with focus on these inequalities are critical for promoting environmental equity and justice. However, implementation of these micro-level policies would require information on impact of various local and regional sources at a finer scale and studies on improving accuracy of this information would prove critical in the race to achieving clean air for all.

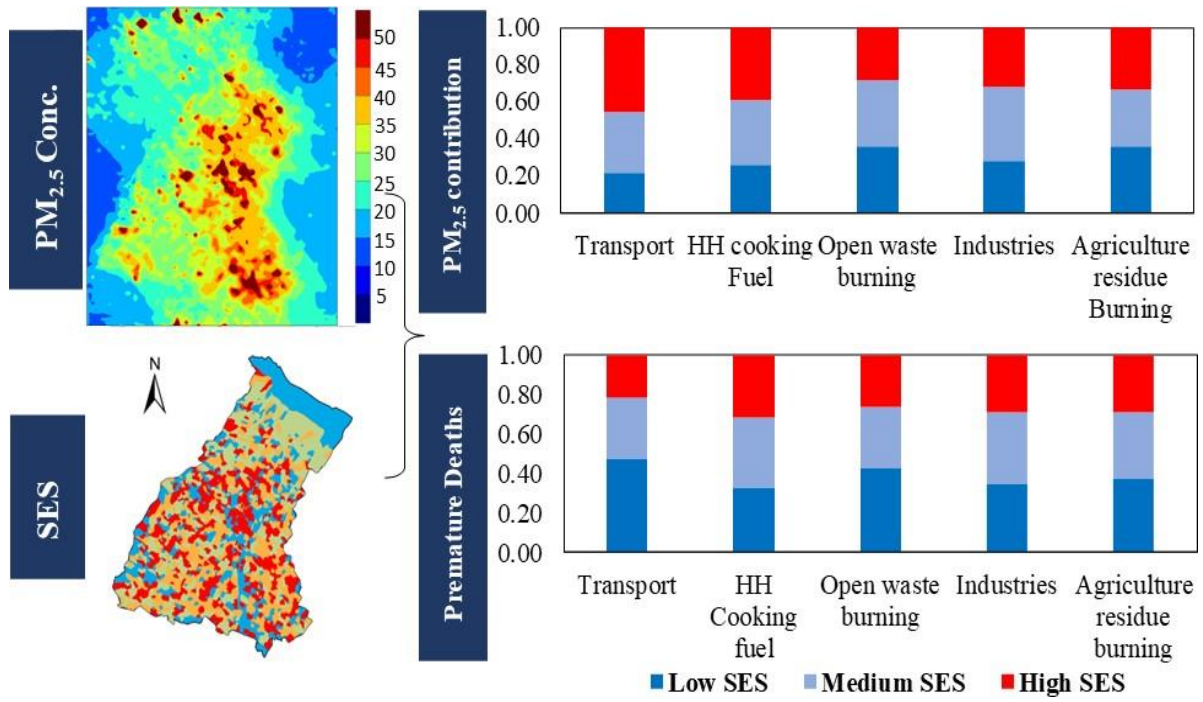
सार

भारतीय क्षेत्रों में परिवेशीय वायु प्रदूषण का स्तर नियमित रूप से खतरनाक स्तर को पार कर रहा है। इन उच्च वायु प्रदूषण स्तरों से मानव स्वास्थ्य पर काफी प्रभाव पड़ता है, जो उपलब्ध कार्यबल की आजीविका को नुकसान पहुंचा सकता है। वर्तमान अध्ययन में छोटे भारतीय शहरों और ग्रामीण क्षेत्रों में होने वाले वायु प्रदूषण में विभिन्न बुनियादी ढांचा क्षेत्रों के योगदान पर सूचना की कमी को संबोधित करते हुए, भारतीय जिले, सहारनपुर में उच्च रिज़ॉल्यूशन पर $PM_{2.5}$ उत्सर्जन का अनुमान लगाया गया है। अवलोकनों से पता चलता है कि शहरी क्षेत्रों में; परिवहन, खुले में कचरा जलाना, घरेलू खाना पकाने का ईंधन, और उद्योग सालाना $PM_{2.5}$ उत्सर्जन में 97 टन (5%), 368 टन (18%), 499 टन (24%) और 1121 टन (53%) का योगदान करते हैं। ग्रामीण क्षेत्रों में; परिवहन, खुले में कचरा जलाना, उद्योग, कृषि अवशेष जलाना और घरेलू खाना पकाने का ईंधन सालाना क्रमशः 236 टन (2%), 1201 टन (11%), 1824 टन (16%), 3732 टन (33%), और 4349 टन (38%) का योगदान देता है। ये योगदान पैटर्न और उनका उच्च-रिज़ॉल्यूशन विश्लेषण वायु प्रदूषण और इसके प्रभाव को कम करने के लिए व्यक्तिगत क्षेत्र के हॉटस्पॉट के आधार पर स्रोतों को खोजने और माइक्रोलेवल गतिविधियों की योजना बनाने के लिए महत्वपूर्ण है। क्षेत्र में घरेलू खाना पकाने का ईंधन जलाने, उद्योगों और कृषि अवशेष जलाने जैसे क्षेत्रों के लिए प्राथमिकता की ओर इशारा करते हैं। हालाँकि, कुछ क्षेत्रों में परिवहन और ठोस अपशिष्ट जलाने वाले क्षेत्रों में भी सख्त कार्यान्वयन की आवश्यकता होगी, क्योंकि ये स्थानीय हॉटस्पॉट की वायु गुणवत्ता तय करने में एक महत्वपूर्ण कारक साबित हो सकते हैं।

अंत में, डिस्पर्जन मॉडलिंग और कंसंट्रेशन रिस्पॉन्स फंक्शन का उपयोग करके स्वास्थ्य प्रभाव मूल्यांकन की सहायता से, अध्ययन क्षेत्र में उच्च रिज़ॉल्यूशन स्वास्थ्य प्रभावों का अनुमान लगाया गया है। विभिन्न जनसांख्यिकीय और सामाजिक-आर्थिक समूहों में वायु प्रदूषण में अलग-अलग योगदान और जोखिम का विश्लेषण करके स्वास्थ्य और आजीविका के प्रभाव का बेहतर पैमाने पर अनुमान लगाया गया है। विकासशील देशों में आबादी के बीच परिवेशीय वायु प्रदूषण से स्वास्थ्य और आजीविका पर असंगत प्रभाव होता है। विशेष रूप से छोटे शहरों और ग्रामीण क्षेत्रों में सूक्ष्म-स्तरीय उत्सर्जन डेटा पर जानकारी की कमी के कारण इन असमानताओं को अक्सर नजरअंदाज कर दिया जाता है। इसलिए, वर्तमान कार्य सतह पर $PM_{2.5}$ सांद्रता के आधार पर अनुमानित स्वास्थ्य प्रभावों का भी विश्लेषण करता है और सुझाव देता है कि शहरी और ग्रामीण क्षेत्रों में प्रति 1,00,000 लोगों पर समय से पहले होने वाली मौतों की दर क्रमशः 158 (95% CI: 122-163) और 143 (95% CI: 65-151) हैं। कुल हुई 6372 वार्षिक असामयिक मौत में से 68% (95% CI: 3321-6987) असामयिक मौतें ग्रामीण क्षेत्रों में होती हैं। सामाजिक-आर्थिक समूहों के बीच उच्च योगदान-जोखिम असमानताओं को दर्शाते हुए, अध्ययन में पाया गया कि वायु प्रदूषण में उनके योगदान की तुलना में, क्षेत्र में कमजोर सामाजिक-आर्थिक स्थिति समूहों में उद्योगों, घरेलू खाना पकाने के

ईंधन जलाने, खुले में कचरा जलाने और परिवहन में $PM_{2.5}$ से क्रमशः 6, 7, 7, 26 और 7% अधिक असामयिक मौतें होती हैं। अध्ययन क्षेत्र में अधिकांश दैनिक समायोजित जीवन वर्ष (DALYs) आर्थिक रूप से कमजोर श्रमिक श्रेणियों में देखे गए हैं। जीवन के इन वर्षों के नुकसान के कारण आय में कमी से बुनियादी जीवन आवश्यकताओं के लिए दैनिक मजदूरी पर निर्भर इन समूहों पर काफी प्रभाव पड़ेगा। इन असमानताओं पर ध्यान देने वाली सूक्ष्म-स्तरीय प्रदूषण शमन नीतियां पर्यावरणीय समानता और न्याय को बढ़ावा देने के लिए महत्वपूर्ण हैं। हालाँकि, इन सूक्ष्म-स्तरीय नीतियों के कार्यान्वयन के लिए विभिन्न स्थानीय और क्षेत्रीय स्रोतों के प्रभाव पर बेहतर पैमाने पर जानकारी की आवश्यकता होगी और इस जानकारी की सटीकता में सुधार पर अध्ययन सभी के लिए स्वच्छ हवा प्राप्त करने की दौड़ में महत्वपूर्ण साबित होगा।

GRAPHICAL ABSTRACT



CONTENTS

ACKNOWLEDGEMENTS	v
ABSTRACT.....	vii
संक्षेप.....	ix
GRAPHICAL ABSTRACT	xi
CONTENTS.....	xii
LIST OF TABLES.....	xv
LIST OF FIGURES.....	xvii
LIST OF ABBREVIATIONS	xix
CHAPTER 1: INTRODUCTION.....	1
1.1. Air pollution affected regions	3
1.2. Disparities in air pollution exposure	4
1.3. Contributing sectors	6
1.4. Limited information on air pollution and sources	6
1.5. Air pollution estimation and source identification	7
CHAPTER 2: LITERATURE REVIEW.....	11
2.1. Air pollution in India.....	13
2.2. High-resolution emission estimation.....	14
2.3. Air pollution from transportation sector.....	18
2.4. Stationary sources in India	20
2.5. Air pollution associated disparities	22
2.6. Gaps identified.....	23
2.7. Research Objectives.....	23
CHAPTER 3: EMISSIONS FROM MOBILE SOURCES.....	25
Graphical Abstract.....	27
3.1. Introduction	27
3.2. Methodology	29
3.2.1. Emission Estimation	29
3.2.2. On-road Vehicle Population & Vehicle survival function.....	31
3.2.2.1. Using vehicle survival function.....	31
3.2.2.2. Using age profile from fuel pump surveys.....	32
3.2.3. Vehicle kilometer traveled.....	33
3.2.4. Spatial allocation of VKTs or Adjusted VKT estimation:.....	34

3.2.4.1.	On-road vehicle population distribution	34
3.2.4.2.	Defining 5×5 km grids and their vehicle activities	35
3.2.4.3.	Vehicle movement from native grid to recipient grids	35
3.2.4.4.	Mapping vehicle activities on road stretches inside 5×5 km	37
3.2.5.	Emission factors.....	40
3.3.	Results	41
3.3.1.	Exhaust and non-exhaust emission	41
3.3.2.	Contribution of individual vehicle Categories	42
3.3.3.	Contribution from different road types	44
3.3.4.	Impact of spatially distributed vehicle movement on non-exhaust emissions...	45
3.3.5.	Comparison with previous studies	46
3.3.6.	Uncertainties and limitations	48
3.4.	Conclusion.....	50
CHAPTER 4: EMISSIONS FROM STATIONARY SOURCES.....		53
4.1.	Introduction	55
4.2.	Methodologies.....	57
4.2.1.	Emission estimation.....	57
4.2.1.1.	Household Cooking Fuel.....	58
4.2.1.2.	Agriculture Residue Burning	62
4.2.1.3.	Solid Waste Burning	63
4.2.1.4.	Industries	64
4.2.2.	Emission Factors	66
4.3.	Results	68
4.3.1.	Annual PM _{2.5} emissions in urban-rural district	68
4.4.	Conclusion.....	71
CHAPTER 5: HEALTH IMPACTS		73
5.1.	Introduction	75
5.2.	Methodology	75
5.2.1.	WRF-CHEM model description and application.....	75
5.2.2.	Health impacts	77
5.3.	Results	78
5.3.1.	Annual surface concentration of PM _{2.5}	78
5.3.2.	Adult premature mortality in urban-rural district.....	81

5.4. Uncertainties and limitations.....	82
5.5. Conclusion.....	82
CHAPTER 6: EQUITY IN CONTRIBUTION AND EXPOSURE	85
6.1. Introduction.....	87
6.2. Methodology	88
6.2.1. Productivity and livelihood impacts	88
6.2.2. Socioeconomic indicator	90
6.3. Results.....	90
6.3.1. Contribution and exposure inequalities	90
6.3.2. Health or livelihood impacts in worker categories	92
6.4. Conclusion.....	95
CHAPTER 7: CONCLUSION AND FUTURE PERSPECTIVE	97
7.1. Conclusion.....	99
7.2. Future Perspective	102
REFERENCES.....	105
LIST OF PUBLICATIONS	124

LIST OF TABLES

Table 2.1: Prevalence of high air pollution in urban as well as rural areas in India	15
Table 2.2: Vehicle flow and density methodologies for high resolution emission estimation from transportation sector	19
Table 3.1: Optimized value of the two parameters of “modified Weibull” survival function...	33
Table 3.2: Daily Vehicle kilometer travel (VKT) with standard deviation (SD) per vehicle for urban and rural areas.	34
Table 3.3: Passengers travelling in travel bins Census of India (2011).	36
Table 3.4: Exhaust emission factor for PM _{2.5} (g/km) for individual vehicle categories with standard deviations among fuel types (ARAI Pune, 2010).....	40
Table 3.5: Non-exhaust emission factors (wear and resuspension) for PM _{2.5} (mg/km) for individual vehicle categories ¹ (Beddows & Harrison, 2021); ² (US-EPA, AP-42)	41
Table 3.6: Comparison of exhaust and non-exhaust emissions from transport sector with previous studies.....	46
Table 3.7: Input data (used in monte-carlo simulation for random number generation) for on-road vehicle population and daily VKT with standard deviation in urban and rural areas of the study domain.....	48
Table 4.1: Primary and secondary fuel used by household of various socioeconomic conditions.....	60
Table 4.2: Amount of HH cooking fuel burnt in rural areas of Saharanpur district.....	61
Table 4.3: Amount of HH cooking fuel burnt in urban areas of Saharanpur district.....	61
Table 4.4: Agricultural production in Saharanpur (year 1997-2018).....	63
Table 4.5: Amount of waste burnt (tonnes/day) in Saharanpur district.....	64
Table 4.6: Activity data and their data sources.....	65
Table 4.7: Emission Factors for household cooking fuel burning, agriculture residue burning, and open waste burning (gkg ⁻¹ of fuel or waste burnt)	66
Table 4.8: Emission factors for combustion technologies (gkg ⁻¹ fuel used) Sadavarte & Venkataraman, 2014	67
Table 4.9: Emission factors for process and fugitive emissions (gkg ⁻¹ production) Sadavarte & Venkataraman, 2014	68
Table 5.1: Physical and chemical schemes used in WRF-Chem	76
Table 6.1: Socioeconomic status of various worker categories in other workers (NSSO, 2012)	94

Table 6.2: Proportion of population in various socioeconomic groups.....	94
--	----

LIST OF FIGURES

Figure 1.1: Currently available (Continuous Ambient Air Monitoring Stations) CAAQMS in India (Source: CPCB)	8
Figure 3.1: Fundamental approach for the high spatial resolution emission estimation and dispersion analysis study.....	30
Figure 3.2. On- road vehicle population from year (2006-2018).....	31
Figure 3.3. Percent distribution of vehicles in different age categories.....	32
Figure 3.4: a) Study domain with rural-urban boundaries and different road types, b) VKT distribution matrix (5×5km grids) and their presumed movement from native grid (grid to which the vehicle belongs) to recipient grids (grids in which the vehicle travels) shown by arrows.....	37
Figure 3.5: Vehicle kilometre travelled per kilometre of road stretches showing traffic density at various locations the study domain	38
Figure 3.6: Typical traffic at 10:00 am IST on roads of the study domain, showing high traffic density location	39
Figure 3.7: Typical traffic at 02:00 pm IST on roads of the study domain, showing high traffic density location	39
Figure 3.8: Typical traffic at 08:00 pm IST on roads of the study domain, showing high traffic density location	39
Figure 3.9: Percent contribution from emission sources to vehicle category annual PM _{2.5} on (a) Urban roads; (b) Rural roads.	42
Figure 3.10: Percent contribution from vehicle category to Annual exhaust and non-exhaust PM _{2.5} on a) Urban roads; b) Rural roads	43
Figure 3.11: Percent share of different road types to (a) total road length (b) exhaust emissions (c) non-exhaust emission.....	44
Figure 3.12: Annual PM _{2.5} emission (tonnes/ km) on individual road stretches, the road stretches are divided based on 5×5 km grids and are used as line area source of pollutant in AERMOD from dispersion study	45
Figure 3.13: Comparison of road type percent share to total PM _{2.5} emissions (exhaust and non-exhaust) between (a) current study approach; (b) vehicle ownership approach; (c) normalized square population density approach	46
Figure 3.14: Normal distribution of the uncertainties associated with PM _{2.5} emission on (a) urban roads, and (b) rural roads	49

Figure 3.15: Comparison of contribution to uncertainty and emissions by individual vehicle categories on (a) urban roads and (b) rural roads.....	49
Figure 4.1: Detailed fundamental approach.....	57
Figure 4.2: (a) Study domain with village and ward boundaries, (b) the highlighted area from figure 4.2(a) shown with its vertices (red dots), used to create macro-level area source emission inventory.	58
Figure 4.3: Contribution of individual infrastructure sectors to PM _{2.5} emissions in urban and rural areas of the study domain.....	69
Figure 4.4: Contribution of individual infrastructure sector to PM _{2.5} emissions in study domain (left) and Saharanpur city (right)	71
Figure 5.1: Jacobian matrix Structure	78
Figure 5.2: Annual spatial concentration of PM _{2.5} from all infrastructure sectors combined and individually	80
Figure 5.3: Micro-level (wards and villages) distribution of SES, Number of DALYs attributed of PM _{2.5} exposure; and Number of premature deaths attributed to PM _{2.5} exposure (from left to right)	81
Figure 5.4: Disability Adjusted life Years (DALYs) attributed to PM _{2.5} exposure.....	82
Figure 6.1: (a) PM _{2.5} load contribution and (b) premature mortality caused by exposure to PM _{2.5} from individual infrastructure sectors in varying socioeconomic categories in urban and rural regions of the study domain	91
Figure 6.2: (a) PM _{2.5} load contribution and (b) Premature mortality caused by exposure to PM _{2.5} from individual infrastructure sector in varying socioeconomic categories in urban-rural district.....	92
Figure 6.3: Proportion of different worker categories in various SES groups.....	93
Figure 6.4: Socioeconomic inequalities in health impacts among various worker categories in rural villages and urban neighbourhoods	93

LIST OF ABBREVIATIONS

GDP: Gross Domestic Product

NCAP: National Clean Air Programme

PM: Particulate Matter

MoEFCC: Ministry of Environment, Forest and Climate Change

MoHUA: Ministry of Housing and Urban Affairs

NCR: National Capital Region

CPCB: Central Pollution Control Board

SES: Socioeconomic Status

CAAQMS: Continuous Ambient Air Monitoring Stations

ECI: Economic Census of India

SECC: Socio-economic and Caste Census

NSSO: National Sample Survey Office

DALYs: Daily Adjusted Life Years

MSW: Municipal Solid Waste

HH: Household

NO_x: Nitrogen Oxides

CO: Carbon Monoxide

VOCs: Volatile Organic Compounds

SO₂: Sulphur Dioxide

CO₂: Carbon Dioxide

CH₄: Methane

N₂O: Nitrous Oxide

NMHC: Non-Methanic Hydrocarbon

GHG: Greenhouse Gases

ARAI: Automotive Research Association of India

ASI: Annual Survey of Industries

GIS: Geographic Information System

GPS: Global Positioning System

IGP: Indo-Gangetic Plains

VKT: Vehicle Kilometer Travel

2W: Two Wheelers

3W: Three Wheelers

4W: Four Wheelers

LCV: Light Commercial Vehicle
HCV: Heavy Commercial Vehicle
EF: Emission Factor
SD: Standard Deviation
IST: Indian Standard Time
USEPA: United States Environmental Protection Agency
IARI: Indian Agricultural Research Institute
CSE: Centre for Science and Environment
COPD: Chronic Obstructive Pulmonary Disease
IHD: Ischemic Heart Disease
LC: Lung Cancer
CRF: Concentration Response Function
IER: Integrated-exposure Response Functions
LPG: Liquified Petroleum Gas
WHO: World Health Organization
MPCE: Monthly Per Capita Expenditure
NDSAP: National Data Sharing and Data Accessibility Policy
LPS: Large point sourcesFO: Fuel Oil
HSD: High Speed Diesel
NG: Natural Gas
FCC: Fluid Catalytic Cracking
GBD: Global Burden of Disease
WRF: Weather Research & Forecasting
NCEP: National Centers for Environmental Prediction
FNL: Final Analysis
NCAR/ACOM: National Centre for Atmospheric Research/Atmospheric Chemistry
Observation & Modeling
EDGAR: Emission Database for Global Atmospheric Research
MOZART: Model of Ozone and Related Tracer Chemicals
GCMs: General Circulation Models
CRF: Concentrations Response Function
RR: Relative Risk
PAF: Population Attributable Function
YLL: Years of Life Lost

YLD: Years Lived with Disability

CI: Confidence Interval

NAAQS: National Ambient Air Quality Standard

NFHS: National Family Health Survey