NITROGEN DIOXIDE EXPOSURE ASSESSMENT AND CHILD RESPIRATORY HEALTH IN INDIA

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INDIAN INSTITUTE OF TECHNOLOGY DELHI

&

THE UNIVERSITY OF QUEENSLAND

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Nitrogen dioxide exposure assessment and child respiratory health in India

by

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&

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This thesis is dedicated to

my father and grandfather

For their endless love, sacrifice, and belief in my dreams.

Your support has shaped who I am today.

Supervisor Certification

This is to certify that the thesis entitled "**Nitrogen dioxide exposure assessment and child respiratory health in India**" being submitted by **Ms Neha Singh** to the Indian Institute of Technology Delhi and The University of Queensland for the award of the degree of **Doctor of Philosophy** is a record of original bonafide research work carried out by her. She has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results contained in this thesis are original and have not been submitted, in part or full, to any other University or Institute for the award of any other degree or diploma.

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Abstract

Air pollution is the leading environmental health risk factor globally. Nitrogen dioxide (NO_2) is a criteria pollutant associated with adverse health effects. Children are the most susceptible group due to developing organs, longer life expectancy, and potential lifelong health impacts. In India, the focus has been mostly on ambient $PM_{2.5}$; hence, understanding the space-time variability of NO_2 and the potential role of different NO_2 sources is required. Moreover, the scarcity of ground-based Nitrogen dioxide (NO_2) measurements poses a major roadblock in conducting a comprehensive exposure assessment and associated health impact studies. Furthermore, no operational monitoring sites in rural India exacerbate the challenge even more.

This work aimed to develop a high spatial scale NO_2 exposure dataset for India and to understand the expected child respiratory health benefits of mitigating NO_2 over India. The four primary objectives are as follows. First—to examine the long-term spatial heterogeneity of NO_2 and its linkage to major contributing sources (e.g., transportation, power plants and industries) across the Indian region. Additionally, it investigated the NO_2 variability in land use patterns and its changes over the years 2005-2019. Second—to develop the first national scale annual NO_2 exposure dataset for India from 2015 to 2021 at a fine spatial scale (100×100 m) using the satellite-based land-use regression modeling technique. Third—to quantify NO_2 exposure in Indian administrative boundaries and disparities in various population subgroups based on wealth index, ethnicity, and place of residence. Fourth—to assess the burden of acute respiratory infections (ARI) among children below age 5 (B5) attributable to ambient NO_2 and to evaluate the health benefits in terms of ARI prevalence if India meets World Health Organisation (WHO) air quality guidelines for NO_2.

We analyzed tropospheric NO_2 vertical columnar densities (VCDs) from the Ozone Monitoring Instrument (OMI) onboard the Aura satellite at a resolution of $0.1° \times 0.1°$ for the period 2005 to 2019. We calculated linear trends in tropospheric NO_2 VCDs and performed a significance test to ensure real changes. We also analyzed the long-term changes in NO_2 VCDs in various settlement classes—high-density urban, low-density urban, rural, and no-settlement using Global Human Settlement Layer data. The spatial analysis found higher tropospheric NO_2 VCDs ($>5\times10^{15}$ molecules/cm^2) in eastern (coal belt with many power plants) and northern India, along with a few locations in central India. The change in tropospheric NO_2 VCDs during the last 15 years showed an increasing trend ($>2\times10^{13}$ molecules/cm^2) in most parts of

India. Tropospheric NO_2 VCDs increased by 12.5% to 29.6% from 2005 to 2019 across all levels of land settlement in India. Here, we suggested considering NO_2 as an important pollutant besides $PM_{2.5}$ and developing a NO_2 exposure model for further impact assessment studies.

For the exposure model, we used a supervised forward additional linear regression method for model development using 804 CPCB monitoring stations (157 automatic and 647 manual) and 209 predictor variables, including satellite NO_2 and geographic variables. Model diagnostics and cross-validation were performed using standard methods. Ordinary kriging was applied to the final model residuals. Our best model with kriging explained 70% variability in NO_2 with a spatial root mean square error of 7.2 $\mu g/m^3$. National population-weighted-average-concentration (exposure) of NO_2 ranged between 22.1 to 22.7 $\mu g/m^3$ from 2015 to 2021. NO_2 exposure levels were highest in states with low socio-demographic index (22.1 $\mu g/m^3$), followed by middle (16.6 $\mu g/m^3$) and high (16.2 $\mu g/m^3$) in 2019. To our knowledge, this is the first such long-term NO_2 exposure model LUR model specific to India and is available to interested researchers.

Over the years, 92% to 94% of the Indian population has been exposed to NO_2 exposure levels exceeding the WHO AQG of 10 $\mu g/m^3$, with cities like Mumbai, Kolkata, and Delhi consistently surpassing the national standards of 40 $\mu g/m^3$. Urban, wealthier, and ethnic majority populations subgroups experience higher exposure levels than their counterparts.

For the epidemiological study, we used Indian National Family Health Surveys, NFHS-4, conducted from 2015 to 2016. We analyzed cross-sectional associations between annual exposures to NO_2 and ARI in B5. Maternal, child, and household factors were adjusted using a multivariate logistic regression model. We performed a stratified analysis based on place of residence for NO_2. The ARI prevalence was 2.82%. We found a 10 $\mu g/m^3$ increase in NO_2 was associated with greater odds of having an ARI (OR: 1.26; 95% CI: 1.2–1.3). We observed evidence of effect modification by place of residence, suggesting greater effects of NO_2 on ARI in children living in rural areas (OR: 1.47; 95% CI: 1.4–1.6). The district-scale health benefit analysis suggested that national ARI prevalence would decrease by up to 7.1% and 14.3% relative to ARI prevalence in 2015–16 if all district achieved their nearest WHO interim targets and if districts met WHO AQG, respectively—helpful in achieving Indian National Health

Policy's goal for non-communicable disease-related premature mortality reduction by 25% by 2025.

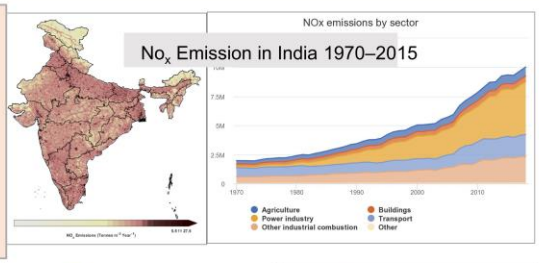
These outcomes indicated that only NCAP for $PM_{2.5}$ reduction is not sufficient; India needs sector-specific emissions reduction policies to reduce ambient air pollutants.

Graphical Representation of Thesis Contents

CHAPTER: 1 Fundamentals of air pollution, health effects, criteria pollutants overview and No_x emissions.

CHAPTER: 2 Literature on NO_2 exposure, health risks, research gaps, and India's challenges.

CHAPTER: 3 Data sources, preparation, methodologies, CPCB, and NFHS data.



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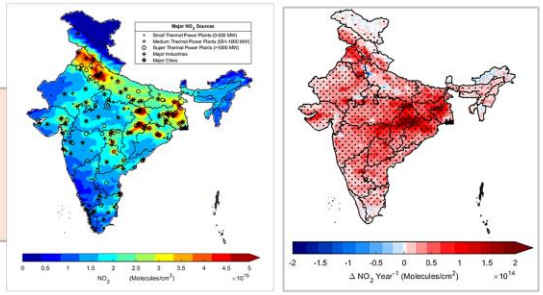

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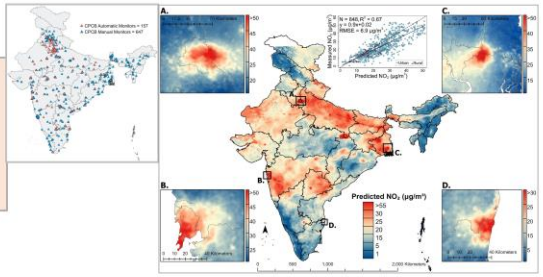
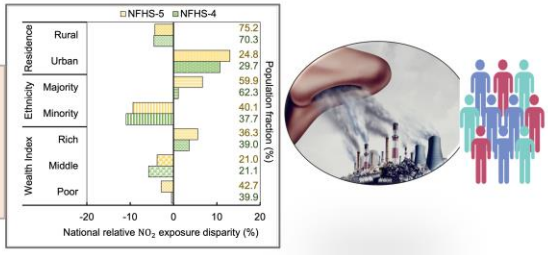


CHAPTER: 6 Explored NO_2 exposure disparities by SES, ethnicity, and residence, highlighting environmental justice concerns in India.



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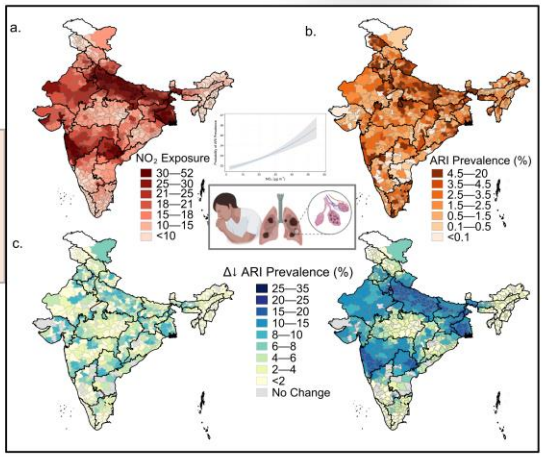

CHAPTER: 8 Thesis conclusion

CHAPTER: 9 Thesis Summary & future directions

संक्षेप (Abstract in Hindi)

वायु प्रदूषण वैश्विक स्तर पर प्रमुख पर्यावरणीय स्वास्थ्य जोखिम कारक है। नाइट्रोजन डाइऑक्साइड (NO_2) प्रतिकूल स्वास्थ्य प्रभावों से जुड़ा एक मानदंड प्रदूषक है। विकासशील अंगों, लंबी जीवन प्रत्याशा और संभावित आजीवन स्वास्थ्य प्रभावों के कारण बच्चे सबसे संवेदनशील समूह हैं। भारत में, मुख्य रूप से परिवेशी $PM_{2.5}$ पर ध्यान केंद्रित किया गया है; इसलिए, NO_2 की स्थान-समय परिवर्तनशीलता और विभिन्न NO_2 स्रोतों की संभावित भूमिका को समझना आवश्यक है। इसके अलावा, जमीन आधारित नाइट्रोजन डाइऑक्साइड (NO_2) माप की कमी व्यापक जोखिम मूल्यांकन और संबंधित स्वास्थ्य प्रभाव अध्ययन करने में एक बड़ी बाधा उत्पन्न करती है। इसके अलावा, ग्रामीण भारत में कोई परिचालन निगरानी साइटें चुनौती को और भी अधिक बढ़ा देती हैं।

इस कार्य का उद्देश्य भारत के लिए उच्च स्थानिक पैमाने पर NO_2 एक्सपोज़र डेटासेट विकसित करना और भारत में NO_2 को कम करने के अपेक्षित बाल श्वसन स्वास्थ्य लाभों को समझना है। चार प्राथमिक उद्देश्य इस प्रकार हैं। पहला- NO_2 की दीर्घकालिक स्थानिक विविधता और पूरे भारतीय क्षेत्र में प्रमुख योगदान देने वाले स्रोतों (जैसे, बिजली संयंत्र और उद्योग) से इसके जुड़ाव की जांच करना। इसके अतिरिक्त, इसने 2005-2019 के दौरान भूमि उपयोग पैटर्न में NO_2 परिवर्तनशीलता और इसके परिवर्तनों की जांच की। दूसरा- उपग्रह-आधारित भूमि-उपयोग प्रतिगमन मॉडलिंग तकनीक का उपयोग करके 2015 से 2021 तक भारत के लिए एक अच्छे स्थानिक पैमाने (100×100 मीटर) पर पहला राष्ट्रीय स्तर का वार्षिक NO_2 एक्सपोज़र डेटासेट विकसित करना। तीसरा- धन सूचकांक, जातीयता और निवास स्थान के आधार पर भारतीय प्रशासनिक सीमाओं और विभिन्न जनसंख्या उपसमूहों में असमानताओं में NO_2 जोखिम की मात्रा निर्धारित करना। चौथा- परिवेशीय NO_2 के कारण 5 वर्ष (B5) से कम उम्र के बच्चों में तीव्र श्वसन संक्रमण (ARI) के बोझ का आकलन करना और यदि भारत NO_2 के लिए विश्व स्वास्थ्य संगठन (WHO) के वायु गुणवत्ता दिशानिर्देशों को पूरा करता है, तो ARI प्रसार के संदर्भ में स्वास्थ्य लाभों का मूल्यांकन करना। .

हमने 2005 से 2019 की अवधि के लिए $0.1° \times 0.1°$ के रिज़ॉल्यूशन पर ऑरा उपग्रह पर ओजोन मॉनिटरिंग इंस्ट्रूमेंट (ओएमआई) से क्षोभमंडल NO_2 ऊर्ध्वाधर स्तंभ घनत्व (VCD) का विश्लेषण किया। हमने क्षोभमंडल NO_2 वीसीडी में रैखिक रुझानों की गणना की और एक महत्व का प्रदर्शन किया। वास्तविक परिवर्तन सुनिश्चित करने के लिए परीक्षण करें। हमने ग्लोबल ह्यूमन सेटलमेंट लेयर डेटा का उपयोग करके विभिन्न निपटान वर्गों - उच्च घनत्व वाले शहरी, कम घनत्व वाले शहरी, ग्रामीण और नो-

सेटलमेंट में NO_2 वीसीडी में दीर्घकालिक परिवर्तनों का भी विश्लेषण किया। स्थानिक विश्लेषण में पूर्वी (कई बिजली संयंत्रों के साथ कोयला बेल्ट) और उत्तरी भारत के साथ-साथ मध्य भारत के कुछ स्थानों में उच्च क्षोभमंडलीय NO_2 VCD ($>5\times10^{15}$ अणु/सेमी^{2}) पाया गया। पिछले 15 वर्षों के दौरान क्षोभमंडल NO_2 VCD में परिवर्तन ने भारत के अधिकांश हिस्सों में बढ़ती प्रवृत्ति ($>2\times10^{13}$ अणु/सेमी^{2}) दिखाई है। भारत में भूमि बंदोबस्त के सभी स्तरों पर 2005 से 2019 तक क्षोभमंडल NO_2 VCDs 12.5% से 29.6% तक बढ़ गई। यहां, हमने $PM_{2.5}$ के अलावा NO_2 को एक महत्वपूर्ण प्रदूषक के रूप में मानने और आगे के प्रभाव मूल्यांकन अध्ययन के लिए NO_2 एक्सपोज़र मॉडल विकसित करने का सुझाव दिया है।

एक्सपोज़र मॉडल के लिए, हमने 804 सीपीसीबी मॉनिटरिंग स्टेशनों (157 स्वचालित और 647 मैनुअल) और उपग्रह NO_2 और भौगोलिक चर सहित 209 भविष्यवक्ता चर का उपयोग करके मॉडल विकास के लिए एक पर्यवेक्षित फॉरवर्ड अतिरिक्त रैखिक प्रतिगमन विधि का उपयोग किया। मॉडल डायग्नोस्टिक्स और क्रॉस-वैलिडेशन मानक तरीकों का उपयोग करके किया गया था। अंतिम मॉडल अवशेषों पर साधारण सिंचाई लागू की गई थी। क्रिगिंग के साथ हमारे सबसे अच्छे मॉडल ने 7.2 $\mu g/m^3$ की स्थानिक मूल माध्य वर्ग त्रुटि के साथ NO_2 में 70% परिवर्तनशीलता को समझाया। NO_2 का राष्ट्रीय जनसंख्या-भारित-औसत-सांद्रण (एक्सपोज़र) 2015 से 2021 तक 22.1 से 22.7 $\mu g/m^3$ के बीच था। NO_2 एक्सपोज़र का स्तर कम सामाजिक-जनसांख्यिकीय सूचकांक (22.1 $\mu g/m^3$) वाले राज्यों में सबसे अधिक था, इसके बाद मध्य (2019 में 16.6 $\mu g/m^3$) और उच्च (16.2 $\mu g/m^3$)। हमारी जानकारी के अनुसार, यह भारत के लिए विशिष्ट पहला ऐसा दीर्घकालिक NO_2 एक्सपोज़र मॉडल LUR मॉडल है और इच्छुक शोधकर्ताओं के लिए उपलब्ध है।

पिछले कुछ वर्षों में, 92% से 94% भारतीय आबादी 10 $\mu g/m^3$ के WHO AQG से अधिक NO_2 जोखिम स्तर के संपर्क में आई है, मुंबई, कोलकाता और दिल्ली जैसे शहर लगातार 40 $\mu g/m^3$ के राष्ट्रीय मानकों को पार कर रहे हैं। शहरी, धनी और जातीय बहुसंख्यक आबादी के उपसमूह अपने समकक्षों की तुलना में उच्च जोखिम स्तर का अनुभव करते हैं।

महामारी विज्ञान के अध्ययन के लिए, हमने 2015 से 2016 तक आयोजित भारतीय राष्ट्रीय परिवार स्वास्थ्य सर्वेक्षण, NFHS-4 का उपयोग किया। हमने B5 में NO_2 और एआरआई के वार्षिक जोखिम के बीच क्रॉस-अनुभागीय संघों का विश्लेषण किया। मातृ, शिशु और घरेलू कारकों को बहुभिन्नरूपी लॉजिस्टिक रिग्रेशन मॉडल का उपयोग करके समायोजित किया गया था। हमने NO_2 के निवास स्थान के आधार पर एक स्तरीकृत विश्लेषण किया। ARI का प्रसार 2.82% था। हमने पाया कि NO_2 में 10

$\mu g/m^3$ की वृद्धि ARI (OR: 1.26; 95% CI: 1.2–1.3) होने की अधिक संभावना से जुड़ी थी। हमने निवास स्थान के आधार पर प्रभाव में संशोधन के साक्ष्य देखे, जो ग्रामीण क्षेत्रों में रहने वाले बच्चों में एआरआई पर NO_2 के अधिक प्रभाव का सुझाव देते हैं (OR: 1.47; 95% CI: 1.4-1.6)। जिला-स्तरीय स्वास्थ्य लाभ विश्लेषण ने सुझाव दिया कि यदि सभी जिले अपने निकटतम WHO अंतरिम लक्ष्यों को प्राप्त कर लेते हैं और यदि जिले क्रमशः WHO AQG को पूरा कर लेते हैं, तो 2015-16 में ARI प्रचलन के सापेक्ष राष्ट्रीय ARI प्रसार 7.1% और 14.3% तक कम हो जाएगा। 2025 तक गैर-संचारी रोग से संबंधित समय से पहले मृत्यु दर में 25% की कमी के लिए भारतीय राष्ट्रीय स्वास्थ्य नीति के लक्ष्य को प्राप्त करना।

इन परिणामों ने संकेत दिया कि $PM_{2.5}$ में कमी के लिए केवल NCAP पर्याप्त नहीं है; भारत को परिवेशी वायु प्रदूषकों को कम करने के लिए क्षेत्र-विशिष्ट उत्सर्जन कटौती नीतियों की आवश्यकता है।

Declaration by author

This thesis is composed of my original work and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, financial support and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my higher degree by research candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

I acknowledge that an electronic copy of my thesis must be lodged with the University Library and, subject to the policy and procedures of The University of Queensland, the thesis be made available for research and study in accordance with the Copyright Act 1968 unless a period of embargo has been approved by the Dean of the Graduate School.

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Neha Singh

Publications included in this thesis

Singh, N., Dey, S., & Knibbs, L. D. (2023). Spatio-temporal patterns of tropospheric NO_2 over India during 2005–2019. *Atmospheric Pollution Research*, 14(3), 101692. https://www.sciencedirect.com/science/article/pii/S1309104223000466

Submitted manuscripts included in this thesis

Singh, N., Knibbs, L. D., Buskirk J. V., & Dey, S. (2023). National, satellite-based land-use regression models for estimating long-term annual NO_2 exposure. *Atmospheric Environment X* —under review.

Statement of Contribution

Paper: Singh, N., Dey, S., & Knibbs, L. D. (2023). Spatio-temporal patterns of tropospheric NO_2 over India during 2005–2019. Atmospheric Pollution Research, 14(3), 101692 (presented in Chapter 4).

Contributors	Contribution
Neha Singh (candidate)	Design of the study (55%) Data management and spatial analysis (75%) Writing of the paper (80%)
Sagnik Dey	Design of the study (35%) Spatial analysis (advice) (20%) Editing of the paper for intellectual content (10%)
Luke D Knibbs	Design of the study (10%) Spatial analysis (advice) (5%) Editing of the paper for intellectual content (10%)

Submitted manuscript: Singh, N., Knibbs, L. D., Buskirk J. V., & Dey, S. (2023). National, satellite-based land-use regression models for estimating long-term annual NO_2 exposure. *Atmospheric Environment X* submitted (incorporated in Chapter 5 & 6).

Contributors	Contribution
Neha Singh	Design of the study (40%) Data management, modelling, and statistical analysis (50%) Exposure predictions (80%) Writing of the paper (75%)
Luke D Knibbs	Design of the study (40%) Modelling and statistical analysis (15%) Exposure predictions (20%) Editing of the paper for intellectual content (15%)
Joe Van Buskirk	Modelling and statistical analysis (35%) Editing of the paper and intellectual content (5%)
Sagnik Dey	Design of the study (20%) Editing of the paper for intellectual content (5%)

Unpublished manuscripts included in this thesis

Singh, N., Dey, S., & Knibbs, L. D. Child respiratory health burden associated with long-term NO_2 exposure in India (included in Chapter 7).

Other publications during candidature

Journal publications (under review):

Amoatey, P., Osborne, N.J., Darssan, D., **Singh, N.,** and Phung, D. Extreme heat, mortality, hospital admissions, ambulance dispatch, emergency department visits, and spatial heat-health vulnerability assessment in Australia: a scoping review. (manuscript submitted to BMC Public Health).

Amoatey, P., Amankona, D., Al-Jabri, K., Chen, M., Izady, A., **Singh, N**., Baawain M. Vehicular Emission Source-Specific Particulate Matter Exposure Concentrations of an Urban Highway: Dosimetry Modelling and Health Risk Assessment. (manuscript submitted to International Journal of Environmental Science and Technology)

Conference abstracts:

Singh, N., Dey, S., & Knibbs, L. (2021, December). Spatial Heterogeneity and Shift in Urban-Rural Concentrations of NO_2 in India over the Last Two Decades (2005-2019). In AGU Fall Meeting Abstracts (Vol. 2021, pp. A25S-08), Orleans, USA.
https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/931264

Singh, N., Dey, S., & Knibbs, L. (2022, January). A National Satellite-Based Land-Use Regression Model for NO_2 Exposure Assessment in India. In *102nd American Meteorological Society Annual Meeting*. AMS. Huston, USA.

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Singh, N., Dey, S., & Knibbs, L. (2022, September). Varying NO_2 from space over India. In *Clean Air Society of Australia and New Zealand (CASANZ) Conference*, Adelaide, South Australia.

Singh, N., Dey, S., & Knibbs, L. (2022, October). Spatial patterns of nitrogen dioxide over India. *Faculty of Medicine HDR Symposium*, The University of Queensland, Brisbane, Australia. (Won people's choice award for presentation).

Singh, N., Knibbs, L. D., Buskirk J. V., & Dey, S. (2022, October). Very First National Scale NO_2 Exposure Assessment in India using Satellite-Based Land Use Regression Model. *The School of Public Health HDR Conference*, The University of Queensland, Brisbane, Australia.

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Singh, N., Dey, S., & Knibbs, L. (2022, December). Change in ARI Burden due to $PM_{2.5}$ and NO_2 in Children under 5 using Two Consecutive Indian Demographic Health Surveys (NFHS-4 & NFHS-5): A Multipollutant Model. In *Fall Meeting* 2022. AGU. Chicago, IL, USA. (Won OSPA award for presentation).
https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1100582

Singh, N., Dey, S., & Knibbs, L. (2023, August). Child Respiratory Health Burden Associated with Long-Term NO_2 Exposure in India. In *India Clean Air Summit* 2023, CSTEP Bangalore, India. (Won best poster presentation award).

Singh, N., Dey, S., & Knibbs, L. (2023, December). Ambient NO_2 exposure disparities across Indian population and demographic groups. In *Fall Meeting* 2023. AGU. San Francisco, CA, USA. https://agu.confex.com/agu/fm23/meetingapp.cgi/Paper/1409039

Contributions by others to the thesis

Professor Sagnik Dey and Associate Professor Luke Knibbs, my supervisors, had substantial input into the conception and design of the research questions, analysis, and interpretation of results. The contributions of co-authors for the submitted paper (Chapter 5) are stated under 'Statement of contribution.'

All chapters

Editorial suggestions were provided by Associate Professor Luke Knibbs (UQ supervisor), Professor Sagnik Dey (IITD Supervisor), Professor Ambuj Sagar (ASMC chair), Professor Gazala Habib (ASMC IITD Expert), and Professor Paul Jagals (ASMC UQ expert).

Statement of parts of the thesis submitted to qualify for the award of another degree

No works submitted towards another degree have been included in this thesis.

Research involving human or animal subjects

This project primarily used satellite and ground monitoring data to develop air pollution exposure data. Secondly, the health effects associated with air pollution exposure were analyzed using India's Demographic and Health Survey (DHS) data. The DHS is a free public-use dataset available upon formal request. The ORC Macro Institutional and relevant ethical review boards in each country approve all DHS surveys. The data files exclude any information that could identify a particular cluster, household, or individual, but the data sets available in the public domain contain sufficient information to describe the data structure. I obtained permission from the ICF-DHS program to use the DHS data in my project.

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Keywords

Air pollution, nitrogen dioxide, ozone monitoring instrument, global human settlement layer, central pollution control board, land use regression model, population exposure, environmental epidemiology, children and acute respiratory infections.

Australian and New Zealand standard research classifications (ANZSRC)

ANZSRC code: 370104, Atmospheric composition, chemistry and processes, 30%

ANZSRC code: 401101, Air Pollution Modelling and Control, 40%

ANZSRC code: 420203, Environmental Epidemiology, 30%

Fields of research classification

FoR code: 3701, Atmospheric Sciences, 70%

FoR code: 4206, Public Health, 30%

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List of Acronyms/ Abbreviations

AF	Attributable Fraction
ALRI	Acute Lower Respiratory Infections
ARI	Acute Respiratory Infections
CAAQMS	Continuous Ambient Air Quality Monitoring Stations
COPD	Chronic Obstructive Pulmonary Disease
CPCB	Central Pollution Control Board
DHS	Demographic Health Survey
EDGAR	Emission Database for Global Atmospheric Research
GBD	Global Burden of Disease
GHSL	Global Human Settlement Layer
GIS	Geographic Information System
GPS	Geographic Positioning System
HR	Hazard Ratio
LMICs	Lower Middle-Income Countries
LUR	Land Use Regression Model
NAMP	National Air Quality Monitoring Programme
NFHS	National Family Health Survey
NO_2	Nitrogen Dioxide
OMI	Ozone Monitoring Instrument
OR	Odds Ratio
PV	Predictor Variables
PWA NO_2	Population Weighted Average NO_2 Concentrations
PWAE	Population Weighted Average Exposure
RR	Risk Ratio
ŔŔ	Relative Risk
SDG	Sustainable Development Goals
TRAP	Traffic Related Air Pollution
WHO	World Health Organisation
WHO AQG	World Health Organisation Air Quality Guidelines
WHO IT	World Health Organisation Interim Targets