Framework for assessing air quality and health impacts of rural emissions in the Indo Gangetic Plain through measurement and modeling

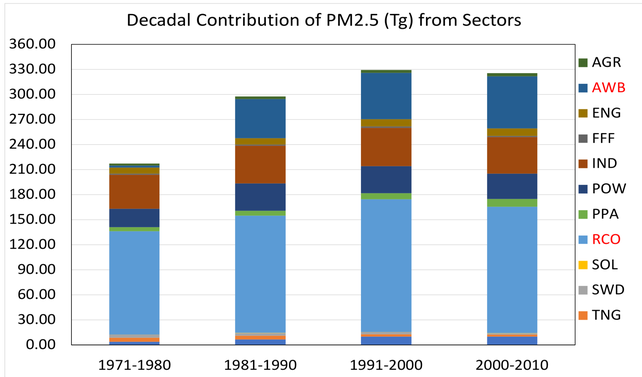
Mrinmoy Chakraborty, Naomi Zimmerman, Amanda Giang
Lab for Environmental Assessment and Policy, Department of Mechanical Engineering, University of British Columbia, Vancouver.

Introduction

- India's rural population largely depends on biomass fuels for cooking and lighting and this contributes to both indoor air pollution and exposure in households, and ambient air pollution [1]
- In northern Indian states, agricultural waste burning takes place during the post-harvest period of April-May and November-December and contributes to a significant load on ambient PM2.5, Black Carbon, VOCs levels over the Indo-Gangetic Plain. [2]
- Sources related to human activities were responsible for the largest proportion of the population exposure to PM2.5 in India [3]
- For the Indo Gangetic Plain, mostly being the rural population, the burden from household air pollution is being disproportionately borne by poor populations who rely on solid fuels for cooking, and poses an enormous challenge for air quality management. [4]

More data needed to understand drivers of rural air pollution over time

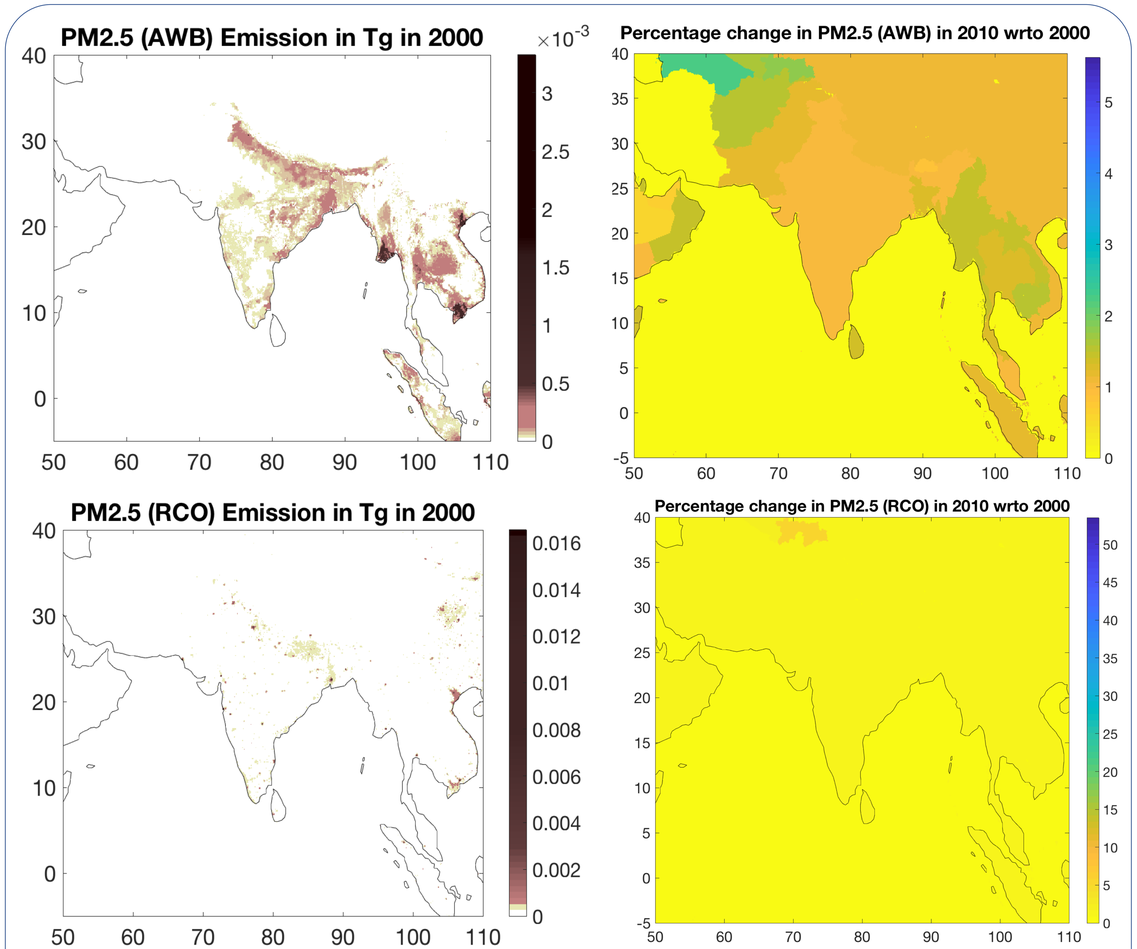
POW: Power generation
ENG: Energy industry
IND: Manufacturing industry
TRO: Road transport
TNG: Railways, pipelines, off-road transport
RCO: Energy for buildings (residential combustion)
PPA: Process emissions from production and application
AGR: Agriculture (excluding soil and agricultural burning)
AWB: Agricultural waste burning
SOL: Soil emissions
SWD: Waste solid and wastewater
FFF: Fossil Fuel Fires



Decadal Sectoral Contribution to PM2.5 concentration from EDGARv43 [5]

- RCO sector is the biggest contributor for PM2.5 among the 12 defined sectors, however, further disaggregation (cooking, heating, lighting) is required to understand future energy transitions and personal exposure
- Updated emission factors differentiating between rural and urban settings are often missing
- Regionally specific emissions factors for activities such as AWB are also often unavailable

Better representation of rural emissions is needed for health impacts estimation and prospective policy analysis



Two Primary sectors contributing towards the Rural India Pollutant (PM2.5) concentration - AWB (Agricultural Waste Burning) and RCO (Residential Combustion).

Research needs for air quality and health impacts

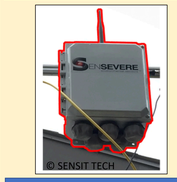
- Uncertainty in measurement and present emission inventory for residential sector
- Robust activity oriented database is missing for rural sector
- Better linkages with intake fraction and exposure pathway
- Indoor and outdoor transport and distribution needs to be evaluated
- Emission profile dependent upon household level and informal activities in rural sector

Research needs for policy

- Energy access for rural populations still a challenge
- Rural pollution often driven by household activities (cooking, heating, lighting, agriculture) that are not well documented
- Energy transition interventions (e.g., efficient cooking technologies and clean fuel supply) still needs evaluation

Study Framework

1. Data Collection: Sampling of air pollutants from residential sector using Low Cost Air Quality Sensor, Survey data, Energy and Health Data from District Centers. We aim to evaluate two test cases – with intervention (improved cooking system and solar lighting) and without intervention (kerosene lamp, conventional cooking)


© SENSIT TECH


© Indiamart

2. Analysis : Indoor and ambient air pollutant levels, correlation among the pollutants with meteorological parameters, tests of association with energy usage conditions (Solid Biomass, LPG, Kerosene)

3. Emission Factor Estimation: Activity-based emission factors will be calculated from different source sector over the sampling regions based on specified activity - heating, cooking, agricultural activity.

$$E_x = EF_x \times Q$$

E_x = Emission of Pollutant x
EF_x = Emission Factor of Pollutant x
Q = Activity or production rate


© The Daily Star

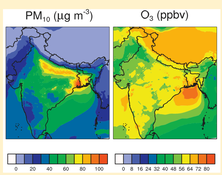

© The Economic Times

4. Emission Inventory : Quantification of pollutants (CO, NOx, SOx, Ozone, BC, PM2.5) from
- Cooking (using dung cakes, dried leaves and wood, kerosene, LPG)
- Residential lighting (kerosene lamp, biomass, micro grid)
- Water Heating (biomass burning, solar heater)
- Agricultural Activity, parboiled rice (kerosene, solid fuel use)

5. Scenario Development:
- Business as usual (BAU) to reflect the current emission profile and its projection.
- Solar microgrid – Residential lighting and water heating is totally achieved by grid connection
- Improved cooking – well ventilated and efficient cookstove achieve reducing the pollutant levels as measured


© UNICEF


© National Geographic Blog



Monthly mean surface concentration simulated from REAS inventory for the month July [6]

6. GEOS-Chem Model Simulation : Simulate the fraction of ambient PM2.5 and ground level ozone due to each major source as identified for each scenario. With existing emission inventories (EDGAR, RAIS, Sadavarte-Venkatraman) and modifications on emission patterns we aim to reduce the uncertainty of model simulation. Use estimates of ambient air pollution to drive health impacts estimates using epidemiological dose-response relationships.

EXPECTED OUTCOMES:

- Solid emission database related to household activities in rural India
- Pollutants (CO, NOx, SOx, CO2, O3, BC, PM2.5) are to be monitored
- Emission factor for actual activities will be evaluated and can be applied further into the emission inventory
- Robust estimation of scale factor for seasonal changes
- Scenario analysis expected to provide policy framework and decision support
- Model simulation can extrapolate the activity oriented data from a regional basis to a state or even country domain

References:
[1] Venkataraman, C. et al. 2010. "The Indian National Initiative for Advanced Biomass Cookstoves: The Benefits of Clean Combustion." Energy for Sustainable Development
[2] Bhuvaneshwari, S., Hiroshan Hettiarachchi, and Jay N. Meegoda. "Crop Residue Burning in India: Policy Challenges and Potential Solutions." IJERPH: 16.5 (2019): 832.
[3] Pandey, Apoorva, Pankaj Sadavarte, Anand B. Rao, and Chandra Venkataraman. 2014. "Trends in Multi-Pollutant Emissions from a Technology-Linked Inventory for India: II. Residential, Agricultural and Informal Industry Sectors." Atmospheric Environment 99: 341–52.
[4] GBD MAPS Working Group. "Burden of disease attributable to major air pollution sources in India." Special report 21 (2018).
[5] Crippa, Monica, et al. "Gridded emissions of air pollutants for the period 1970–2012 within EDGAR v4. 3.2." Earth System Science Data 10.4 (2018): 1987-2013.
[6] Saikawa, Eri, et al. "Uncertainties in emissions estimates of greenhouse gases and air pollutants in India and their impacts on regional air quality." Environmental Research Letters 12.6 (2017): 065002.

Acknowledgements: *SERB-DST, Govt. of India; NSERC Discovery Grant*