Improving North India Air Quality

Science, Technology and Society Programs

Proposal for an Open Science Public Benefit Initiative

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Objective

To

initiate, ideate, integrate and implement

feasible and high-impact multi-dimensional solutions

to improve North Indian air quality

through systemic and collaborative interventions

in science, technology and society

at human, building, neighbourhood, community,

administrative unit, city and state scales and canvases.

Inspiration

1. **Idea**
   - Work with a theory of change, not a theory of action
   - How can you think like an Indian for India?
2. **Institution**
   - Coordinate, don’t command. Garden, don’t build
   - Private ARPA: Shifting the impossible to the inevitable
3. **Innovation**
   - Doing science online
   - The trouble in comparing different approaches to funding
4. **Importance**
   - South Asian Air Quality - Open Philanthropy
   - The Fable of the Dragon-Tyrant
5. **Integration**
   - Is massively collaborative mathematics possible?
   - How To Solve Problems: A mathematician’s outlook
   - A Mathematician’s Apology

Team

Ramanujan Labs is an R&D-focused sustainability company as a systems integrator and technology accelerator spanning air & water quality, soil & crop health, and renewable energy.

The team consists of:

Roshan Shankar has been an advisor in Delhi Government since 2015. He is also a PhD candidate at Princeton University in Civil and Environmental Engineering working on sustainable, resilient and healthy cities. He holds two graduate degrees in public policy and engineering from Stanford University and was formerly an RA with MIT J-PAL.

Prasun Bansal holds degrees in Mechanical Engineering, Aerospace Engineering and Management from IIT Delhi, Stanford and IIM-Ahmedabad respectively. Previously he has worked with NASA and Boeing. His research focus lies in design and development of self-sustaining systems and multidisciplinary optimization.

Our Theory of Change

1. **Foster collaboration** between diverse individuals and institutions with useful specialized knowledge and canvases of impact to create strategic and open data, information, products and services.

1. **Design and implement** do a pilot, proof of concept and proof of stake projects as a social or technical innovation that has a high probability of scale through government, private sector or civil society.

1. **Large Scale impact** through targeted manufacturing/management, research/governance and design/operations to create novel air quality measurement and abatement solutions currently at low technological or social readiness.

1. **Stress-test, monitor, evaluate and refine** the aforementioned process to run research and deliver results that wouldn't be possible otherwise!

Constraints

1. **Information**
    - Lack of publicly available information with high granularity, temporality and fidelity
    - Paucity of scientific policy mindset within the State

1. **Knowledge**
    - Academia has low incentives to deliver high-quality scientific research for impact
    - Poor collaboration in applied and social sciences amongst researchers

1. **Resource**
    - Shortfall in quality of human and financial capital in the private sector for environmental impact
    - Minimal capacity of operational experts in environmental projects in state and civil society

1. **Administration**
    - Shortcomings in institutional coordination
    - Scant capacity for inter-organizational coordination

1. **Rationality**
    - Shortage of public action by citizens and consumers at scale
    - Oversupply for inaccurate information through media and social media

State of Air Quality Measurement

1. Types of sensors and data have different granularity, temporality, cost and price.
    a. **Physical sensors:** Different gases, methods, size, price, precision and accuracy (PureLogic, Atmos, Purple Air, Logic Ladder, CATS Global, Bosch, Philips, GE, CPCB)
    b. **Weather**: IMD, state agencies, Skymet India, GFS, ECMWS, WSI and MDA Weather
    c. **Satellite**: SpaceX, Planet, VegaMX, Pixxel, NASA, ISRO and JSA

2. Data should have high quality, reliability, uniqueness, granularity, availability, accessibility, legitimacy, validity, accuracy, precision, consistency, completeness and comprehensiveness.
    a. All current sources lack at least 5-8 characteristics of good data.
    b. Most sensors depend on Chinese technology and manufacturing which inflates baseline cost
    c. Viability gap funding for researchers is scantily available
    d. Most institutions have no incentive to measure and report accurate air quality data
    e. Satellite and CCTV data can be utilized with sensors for comprehensive data
    f. AQI still utilizes a polynomial function, is not modified for every geography especially in South Asia and application of higher-dimensional sparse statistics on multi-modal data has high potential for impact.

State of Air Pollution Abatement

1. Government and Bureaucracy
    a. Lack of political will and public buy-in.
    b. Fragmented set of uncoordinated actors and actions in the political and bureaucratic executive.
    c. The state's ministries are organized by function, not outcomes.

1. Market and Civil Society
    b. No ecosystem of policy and business entrepreneurship for public problem solving
    c. Investment and expenditure is needed on a mission mode without rent-seeking
    d. Market actors such as businesses and startups have not been made into active partners through futuristic regulation and collaborative policy-making.
    e. Lack of resilient and coordinated stewardship that brings together businesses, NGO, government, academia, judiciary, bureaucracy, faith-based organizations and media

1. Academia, Media and Social Media
    b. Undeveloped research ecosystem for innovation.
    c. Lack of solution-oriented media coverage.

Proposed Initiatives

Information Dissemination

1. Open and Strategic Air Quality Network
2. Information-Knowledge Dissemination (for policymakers, quasi-judicial and judicial bodies)
3. The state of North India's cardiovascular and respiratory health with schools

Knowledge Co-Production

1. Air quality hardware research and development intervention
2. Air quality software and technology initiative
3. Transition TRL for novel sustainability solutions

Collaborative Implementation

1. Air pollution abatement solution: deployment, monitoring and evaluation
2. Interventions at Coal plants and Brick Kilns
3. Site interventions for landfills, crematorium and tandoor
4. Village gauthans for waste-to-value creation
5. Gaushala and dairies to use stubble as fodder
6. Scaling crop diversification in Punjab

Project 1: Open and Strategic Air Quality Network

A. **Evaluate various low-cost sensors**
   - The market has multiple indigenously assembled sensors and initiatives
   - Evaluate their functioning and data

A. **Pilot high-quality laser sensors to conduct air pollution measurement at scale**
   - Gas sensors are the industrial standard and need calibration and maintenance
   - Laser sensors can disruptively reduce the quantum of sensors and their maintenance

A. **Dense proliferation of low cost sensors in one constituency in Delhi and one district in Punjab**
   - Hyperlocal insights from a dense network of sensors can help define the problem at different scales like individual, building, community, neighbourhood, district, city and state
   - This will assist with creation of resource abatement curves for various initiatives and actions

A. **Third-party measurement to assist in nudging for cost-effective and efficient abatement**
   - Targeted measurement at schools, colleges, hospitals, coal plants, brick kilns, tandoors, landfills and crematoria across North India
   - Several institutions don't have the incentive and/or access for air quality researchers to measure and report air pollution statistics

A. **Increase awareness of air quality and public transit effectiveness**
   - Delhi has 5000 bus-stops with 100 top bus-stops generating 90% of traffic
   - LED screens at 100 bus-stops with bus arrival times and air pollution sensors will help generate public debate and discussion

Project 2: Information and Knowledge Dissemination

1. Create a Multi-disciplinary hub for generation of Knowledge around Environment and Sustainability
    - Consisting of 10 fellows from architecture, engineering, law and communication
    - Engaged in creation, coordination, collaboration and translation of impactful research

1. Agenda: Information Dissemination for policymakers, quasi-judicial and judicial bodies
    - Open-source white-labelled free-to-use content
    - Low-cost digital media hub and studio that assists creators with communication
    - Create links with professional and strategic media for public relations and publicity
    - Ensure wider dissemination of impactful and important content and campaigns
    - Work across the sustainability and air quality ecosystem

1. Stakeholders for information dissemination and action include
    - MPs, MLAs, Bureaucrats and people in public policy space
    - National and State Commissions for Women and Protection of Child Rights
    - Supreme Court, High Courts, National Green Tribunal

Project 3: Measuring North India's cardiovascular and pulmonary health

1. Utilize public and private schools in North India to measure the cardiovascular and respiratory health of North India through students, parents and neighbours.

1. Train school students to measure
    - Cardiovascular and pulmonary health using high quality and cheap ECG and PFT of various house members
    - Carry out regular measurement of indoor and outdoor air quality

1. Create and deploy STEM learning programs
    - Modules designed around Sustainability, Environment and Ecology, IoT, AI, Robotics and Sustainability for students from K-12 at different levels
    - Actions include making of air purifiers, masks and air quality sensors

1. Generate regular snapshot of air quality impact on short-term and long-term cardiovascular and respiratory health of North India through school students and their families

Project 4: Air quality hardware research and development

1. **Run a mobile monitoring system for air quality measurement across Delhi**
   - For verification of pollution complaints and live analysis of data at hotspots
   - Operationalize non-functional mobile monitoring air pollution system with IIT Delhi
   - Through viability gap support for equipment and researchers

1. **Conduct scientific research on chlorides for North India air quality**
   - Measure variation of chlorides in the gas phase using a continuous HCl monitor
   - Co-locate with continuous PM speciation equipment
   - Study the simultaneous measurements of gas and particulate phase chlorides
   - Understand the physical and chemical mechanisms leading to the high chloride levels
   - Ascertain the source of HCl emissions

1. **Seed grant for high-impact research with IITs**
   - X-Prize equivalent for indigenous low cost PM sensor of Rs. 2000-5000
   - Supporting research and development for sodium and potassium as a battery

Project 5: Air quality software and technology initiative

1. **Software engineering and Information Technology Initiative**
    - Apply advanced computational methods and sparse higher-dimension sparse statistics for air quality and toxicity
    - Use data from sensors, satellites, CCTV and other information sources
    - Work with Satellite data from NASA and IARI to monitor and ameliorate nitrates, carbon and crop types in North Indian agriculture
    - Plug and play API support for governmental, private and academic air quality data.

1. **Information analysis by leveraging various sensors, metadata and heterogeneous factors**
    - Meteorological factors (e.g., temperature, humidity, visibility etc.)
    - Local factor that captures the quality of the area such as greenery, presence of industry, residential information etc.
    - Vehicular traffic congestion information to estimate pollutant concentration of an area
    - Modelling seasonal risks of in combination with epidemiological data
    - Integration of data sources in waste management and traffic data into prediction models.

1. **Generate a India specific Air-Toxicity Index**
    - Take into account the specific toxins present in Indian conditions
    - Toxicity for impact of health by various toxins

Project 6: Transition TRL for novel sustainability solutions

TRL : Technology Readiness level. NASA defines TRL from 1 (basic principles) to 9 (in-production technology)

1. **Take various projects from TRL 3 to TRL 7**
    - Work with national research labs (CSIR) and institutes of excellence (IIT, IIM)
    - Identify and fund projects that are high impact
    - Aid technology readiness transition from concept and science to industry-readiness
    - Generate a business case for the technology adoption

1. Potential projects
    - **Material**
        - Geopolymer concrete and cement from industrial wastes
        - Particle board from rice husk
        - Evergreen hybrid composites of parali and industrial waste
        - Biodegradable cutleries, cups, glass, and plates from agricultural waste
    - **Process**
        - Improved treatment system for dung, fats, oil and grease management in slaughterhouse
        - Low cost technology for converting biomass wastes into nutrient rich biochar
        - Anaerobic gas lift reactor (AGR): a high rate biomethanation technology to treat organic solid waste for the generation of biogas and bio manure from organic waste
    - **Product**
        - Biofilter: technology for industrial odor control
        - Mobile pyrolyser for turning agricultural waste into energy and fertilizer
        - BFBR: A high-rate anaerobic reactor for complex wastewater treatment
        - Green/renewable bio-hydrogen (H2) and platform chemical production from biogenic (solid /liquid) waste
        - Filters for HVAC systems (window AC, ducted ACs, industries)

Project 7: Air pollution abatement solution: deployment, monitoring and evaluation

1. Study various pollution abatement solutions in Delhi and Punjab
    - At the assembly constituency and district level
    - Deploy multiple sensors, studies and solutions within pilot jurisdiction
    - With support from public representatives, bureaucrats and technocrats
    - Monitor and evaluate at district, ward and constituency levels

1. Creation of a scientifically sound and managerially effective system to deploy, monitor and evaluate air pollution abatement solutions
    - Production of resource abatement curves for cost effectiveness
    - Maximize deployment of government and private capital towards solution deployment

1. Evaluate the efficacy of various interventions at different scales
    - **Individuals:** Warm clothing, heaters, purifiers, masks, better chulhas, LPG substitution of chulhas, Tandoor, usage of natural abatement methods (jute and carbon)
    - **Building:** Road washing, mechanized sweeping, smog guns, water spraying, TiO2/reflective paint, ESP, HEPA filters in HVACs, crematorium, mechanistic innovation
    - **Community:** Composting sites, wind flow screens, biogas plants, smog tower, seeder/harvester/thresher utilization and uptake
    - **Neighbourhood:** Efficient brick kiln and chimney design, landfill interventions like biomethanation, industrial water scrubber
    - **District:** Coal plants process/material improvement

Project 8: Interventions at Coal plants and Brick Kilns

1. Replacing coal with crop residue in power plants
    a. Parali has gross calorific value like domestic coal at 14-15 MJ/kg.
    b. Landed cost of parali delivered to power plant is comparable to domestic coal and far cheaper than imported coal
    c. 9 power plants in Punjab, Haryana and NCR can consume 25% of total parali generated.
    d. 500 MW plant can burn up to 160,000 tons of parali each year. For this target of 3.2 Lakh kg of parali per year per MW is needed.
    e. Needs SPOC (Single Point of Contact) in each block for the power plant for parali purchase like farmer cooperatives, private Enterprises or panchayats.
    f. SPOC to maximize use of baling machines to ease logistics at Rs 450 per ton.
    g. Industry-defined Stubble Quality Metrics (SQMs) to be defined including but not limited to calorific content, moisture, density, ash content and crop variety for smooth processing.
2. Process and technical improvements at coal plants and brick kilns
    a. Operationalize scrubbers, run electrostatic precipitators and manage fly ash at coal plants
    b. Redesign and optimize utilization of inputs and functioning of brick kilns through policy and engineering interventions that can be scale.

Project 9: Site interventions for landfills, crematorium and tandoors

Within cities and urban geographies, three sites of air pollution which can be improved through low-cost engineering interventions are landfills, crematorium and tandoors.

For these three different types of sites, we propose to do the following for these three types of sites in Delhi, NCR and North India:

- Baseline data collection on number, size and typology
- Primary data collection of ambient air quality, emission characteristics and health effects
- Best global practices in design and operation
- Open-source design of high-quality low-cost interventions on existing sites to improve air quality
- Pilot implementation of aforementioned interventions in Delhi and NCR
- Recommendations for state policy and engineering interventions at municipal and site scale

Project 10: Village gauthans for waste-to-value creation

1. At a 5 acre site, the village can setup multiple activities like a composting yard (2 acres), a bio-gas plant (0.5 acres), briquetting / charring plant (0.5 acres), cattle rearing and resting area (1.5 acres), packaging & cutlery unit, brick kiln supply chain, straw maker, handicraft unit and farmer education center (0.5 acre)
2. Industries should be encouraged to do CSR, adopt a block or district to provide stewardship for inputs and outputs, and be a connector for cooperatives and entrepreneurs with experts to identify the lands, equipments, processes and tools needed.
3. Universities, research institutes and national research labs should chip in with agricultural, environmental, chemical and biological technology and know-how that improves how they rear animals, compost various types of biomass, setup biogas plants, briquetting plants and other solutions.
4. CSIR labs like NEERI, NIIST and others have satellite data to analyze available biomass and animals in a block, technologies and patents that help convert waste to value and methods to suggest the site, size, system, process and technologies of the Gauthans to be set up.
5. One-time 50 percent capital subsidy for setting up the buildings, fencing, composters and equipment like rakers, earth movers, tractors and packers should be provisioned. To avoid allegations of favouritism, village should not give the lands for free, but instead seek a discounted rent for the land use (which is within the range of rentals for barren lands; somewhere in the range of Rs 5,000-10,000 per acre per year).

Project 11: Gaushala and dairies to use stubble as fodder

1. Animals like cows eat around 6-8 kg of dry fodder a day. Punjab, for example, has approximately 25.3 lakh cows and 40.2 lakh buffaloes (2019 Livestock Census). They alone could consume 14 lakh tonnes of Parali in just a month. This represents approximately 10 % of the 133 lakh tonnes of Parali produced in one cultivation season.
2. Farmers in other states feel that rice parali when mixed with other greens and jaggery makes it much more palatable to cows. The use of ligninolytic fungi and their extracellular ligninolytic enzymes for treatment of rice straw has been shown to result in degrading cellulose and hemicellulose contents which improve its nutritional value while being practical, cost-effective and environmentally-friendly approach for enhancing the nutritive value and digestibility of rice straw.
3. This win-win situation can be made possible with the help of initiatives like launching a massive awareness drive which included starting a YouTube channel and forming WhatsApp groups of villagers, sanctioning residue management machines to the farmers, and deploying mobile vans to educate, motive and assist farmers to create value from waste instead of noxious fumes. Farmers can be incentivized to follow the Pathankot model, if the state government subsidised the cost of the Parali by asking dairies or CSR funds to cover the transport charges.
4. Alternatively, the state government can also procure Parali at Rs 1/kg and store at its Panchayat sites, Food Corporation of India sites, power plants, and dairy farms. The state should strive to implement this policy in each district of the state and especially in districts with a higher number of cattle.

Project 12: Scaling crop diversification in Punjab district

1. **Scaling crop diversification in Punjab**
    a. Awareness, sensitization, capacity building and sensitization
    b. Evolution of sustainable alternatives through technology, green business and crop diversity
        i. Happy seeder, super seeder and zero drill
        ii. Rice straw baler, Direct seed rice cultivation and PUSA biodecomposer
        iii. Compost turner and Soil incorporation
        iv. Organic and millet farming, cotton and mushroom cultivation
        v. Mulching, green energy, eco-cutlery, eco-housing and compost
    c. Policy and society interventions to ensure linkages to livelihoods and incomes
        i. Handholding support: Leadership development, youth programs, district initiatives
        ii. Capacity building: Dialogue meetings, farmer field schools, natural farming workshop
        iii. Sensitization: Door to door visits, online webinar, farmer meetings, Chetna yatra
        iv. Awareness: IEC, Nukkar Natak, cultural programs, songs, films, documentaries, social media initiatives
    d. Partner with FPOs, non-profits, cooperatives and startups to bring scale to interventions

How will we scale impact across function and type?

1. Scaling across geographies through the state
    a. Judiciary: Technical assistance to NGT, Supreme Court and High Courts
    b. Executive: Flexible program support to
        i. Government of India {Environment, CPCB, Power}
        ii. Delhi Government, State Governments of UP, Haryana and Punjab {{Industry, Power, Agriculture, Commerce, Transport Environment}
        iii. District Magistrates
    c. Legislature: Advocacy with MPs and MLAs
2. Market
    a. Funders (Platform to connect and co-fund projects)
    b. Implementers (Integrate and scale work of startups, academia and research labs)
3. Society
    a. Universities: Research and development capability
        i. IIIT Delhi, IIT Delhi, IIT Bombay,
        ii. IIM-Ahmedabad, IIM-Bangalore, AIIMS
        iii. Princeton, Stanford, MIT, Harvard
    b. Youth organizations (Implementation capacity and operational support)
    c. Policy/governance institutions (Knowledge creation and research collaboration)
        i. NASA, ISRO
        ii. IARI, CSIR: NEERI, CSIR: NIIST
    d. International Organizations (Inter-country collaboration and inter-city communication): IDInsight, WRI, Kheti Virasat Mission
4. Media (Public communication and science communication)
5. Digital Media (Narrative Communication and Innovative Content)