Continuous real-time monitoring of indoor and outdoor air pollution using low-cost sensors

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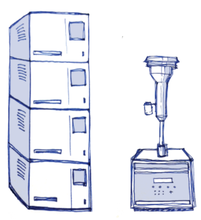
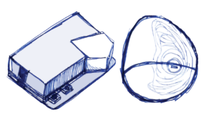
The Problem

- India is home to 13 of the 20 most polluted cities ($PM_{2.5}$) in the world[1]
- $PM_{2.5}$ is attributed to 47 deaths per 100,000 Indians[2]
- elevated indoor levels of CO_2 and VOCs can decrease cognitive function by up to 61%[3]
- fewer than 20 regulatory grade monitoring stations in Delhi (DPCC, SAFAR, CPCB, US) with little spatial and temporal resolution
- data is not accessible to the public
- IAQ is monitored using insufficient sensors
- no actions are taken



Research Grade

Quantitative Low-Cost

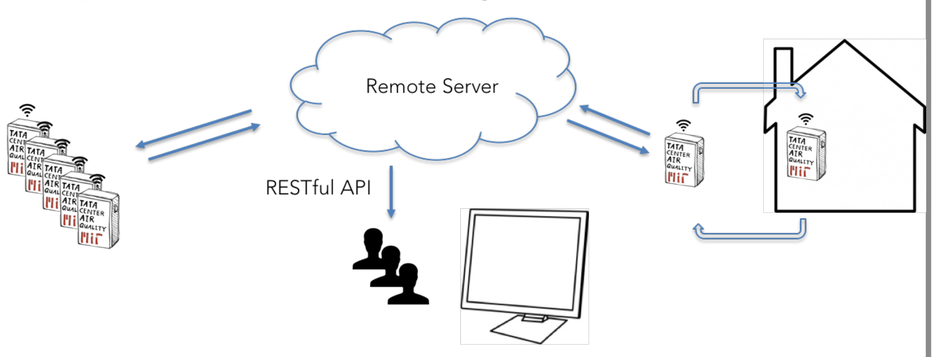


DIY / Low-Cost

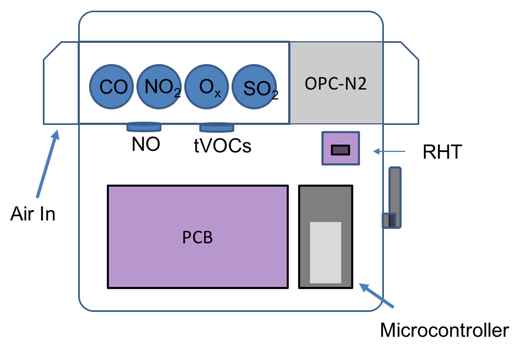
	Research Grade	Quantitative Low-Cost	DIY / Low-Cost
COST	$50k - $100k	~$1000	$10 - $500
UNITS / CITY	1 - 20	100 - 1000	1000's
SENSITIVITY	<1ppb, <1µg/m3	~ppb, ~µg/m3	???

Proposed Solution

- deploy a network of quantitative low-cost sensors across India
- measure gas and particle-phase species with high accuracy and reliability
- generate a robust dataset that be used for air quality monitoring as well as atmospheric chemistry
- generate **actionable intelligence** from our data



Prototype A – 10 units

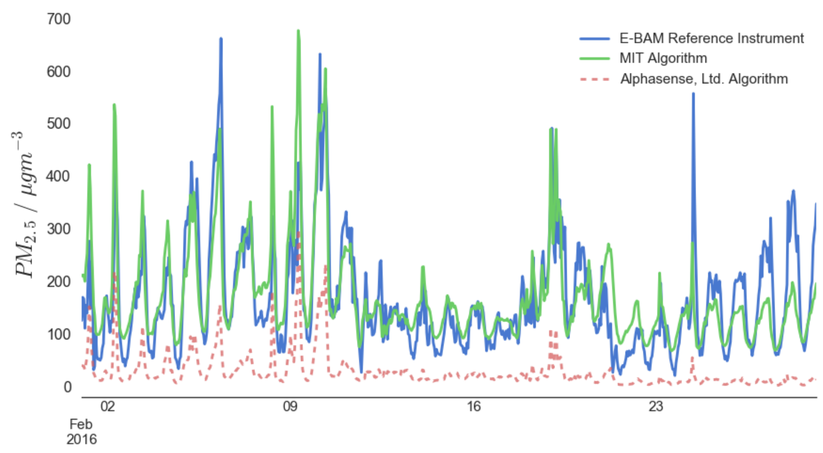


Cost: ~$1500/unit

Size	20cm x 25 cm x 10 cm
Weight	1.6 kg
Data	30 s intervals
Communication	2G / 3G
Particles	380 nm – 17,500 nm
Gases	CO, O_3, NO, NO_2, SO_2, tVOCs

Data

Ambient $PM_{2.5}$ at Connaught Place, Delhi



Results

- we can begin to isolate sources (source apportionment) and see individual plumes
- the particle size distribution is seasonally dependent

Value Proposition

- IAQ monitoring equipment market will be $5.6B USD by 2020[4]
- projected HVAC integration market size in India is $1.2B USD based on potential electricity cost savings
- projected ambient monitoring market in India is $40M USD based on 1km^2 grid-scale of major cities

Next Steps

- long-term co-location of sensors with regulatory grade instruments
- indoor air quality pilot study
- integration of sensors with HVAC system for real-time controls
- expand ambient monitoring to 100 sensors (Delhi)
- development of a comprehensive low-cost VOC sensor
- find partners and explore manufacturing opportunities

Acknowledgments

This work is supported by the Tata Trusts.

References

[1] World Health Organization
[2] Apte et al., Environmental Science and Technology. Addressing global mortality from ambient PM2.5 (2015)
[3] Allen et al., Environmental Health Perspectives. Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments (2015).
[4] Navigant Research

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