Indoor Air Quality Dataset with Activities of Daily Living in Low to Middle-income Communities

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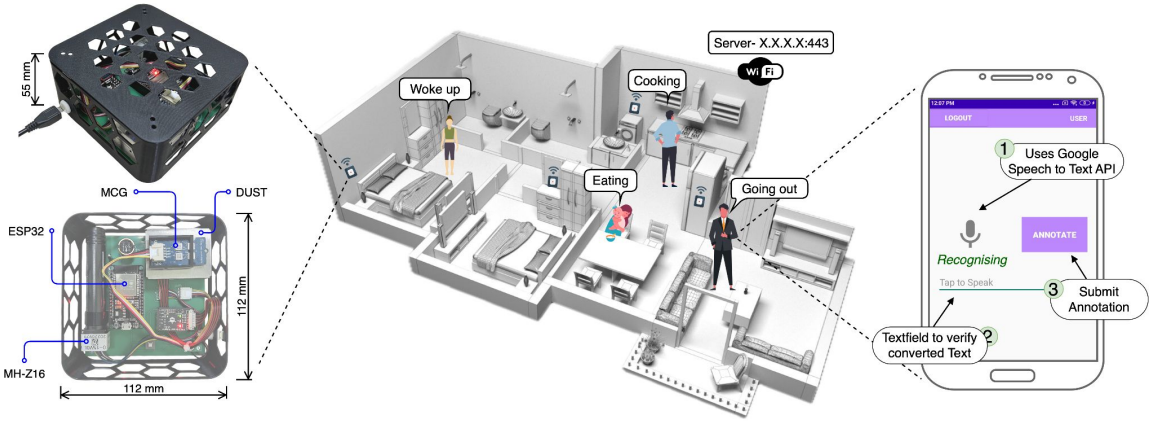

Project Page: https://ubinet-iitkgp.github.io/ubinet/pages/DALTON
GitHub Repo: https://github.com/prasenjit52282/dalton-dataset
Paper: https://arxiv.org/abs/2407.14501

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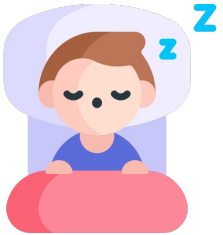
What Influences Indoor Air?

Research indicates that **people spend** approximately **90 percent**[1] **of their time indoors**

Indoor Air Quality mostly influenced by the daily household activities and practices like

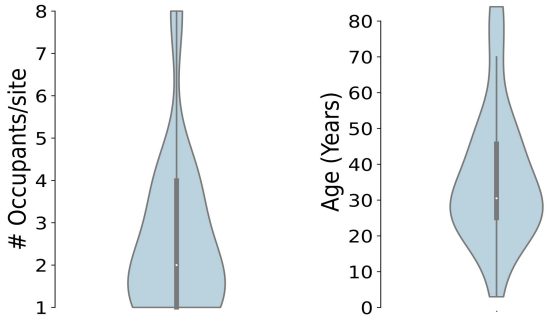
- ❑ Cooking
- ❑ Sleeping
- ❑ Incense sticks
- ❑ Leftover food scraps
- ❑ . . .

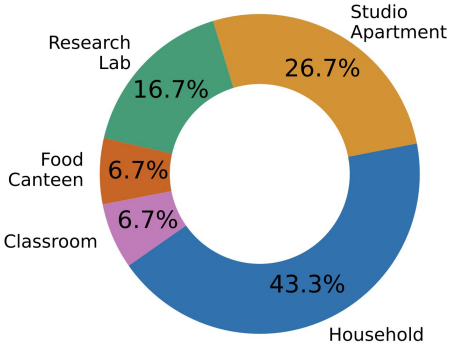


[1] EPA, “The Inside Story: A Guide to Indoor Air Quality.” https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality, 2023.

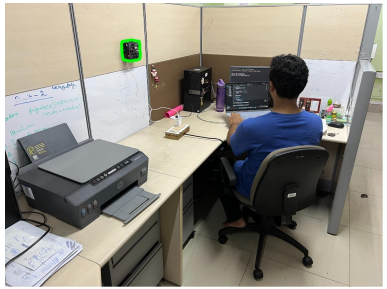
Image sources: https://www.flaticon.com/

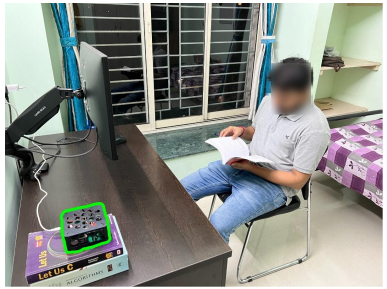
Large-scale Field Deployment





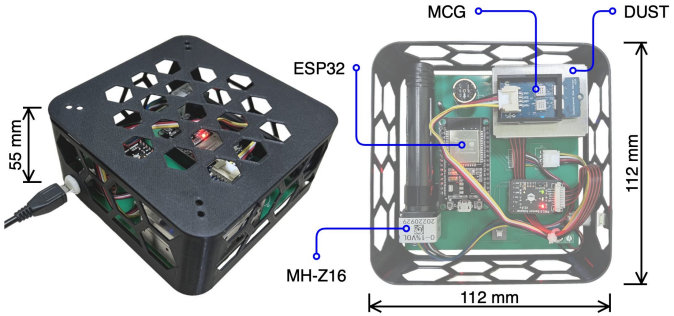
- **30** measurement sites
- Across **four** cities in India
- For over **six** months
- **46** occupants participated

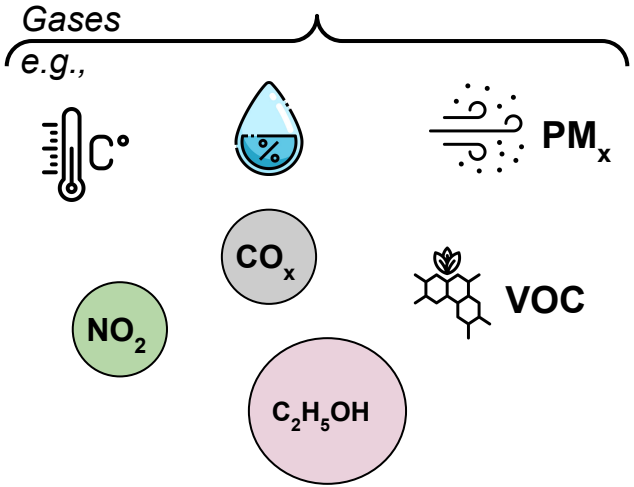


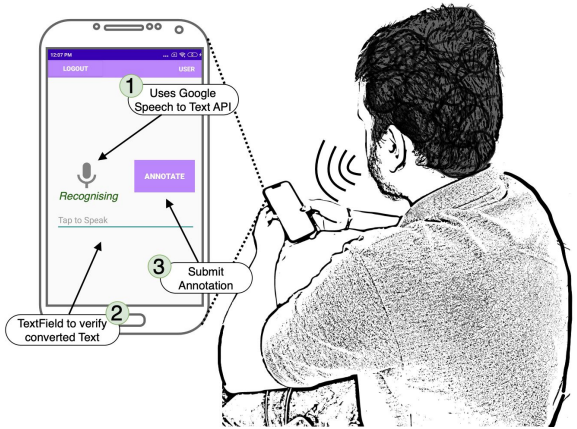


- The images shows real-world deployment scenarios of the **DALTON** sensing module

Data Collection Apparatus







- **VocalAnnot** app helps to track activities
- **DALTON** measures pollutants

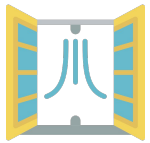
Summary of the Field Deployment

City		Site		Occupants		Ventilation			Air Condition		Cooking Medium		
Name	Type	Site Type	# Sites	Female (%)	Income	Window	Vent-slit	Fan	W	S	LPG	Microwave	Kerosene
Bankura	Rural	Household (H1-H13)	2	50	Low	✓	✓	✓	✗	✗	✓	✗	✓
Durgapur	Suburban		2	50	Middle	✓	✓	✓	✗	✓	✓	✓	✗
Kolkata	Urban		4	44									
Kharagpur	Suburban		5	60	Middle	✓	✓	✓	✓	✓	✓	✓	✗
		Apartment (A1-A8)	8	33	Low	✓	✗	✓	✗	✗	–		
		Food Canteen (F1-F2)	2	50	Middle	✗	✓	✓	✗	✗	✓	✗	✗
		Research Lab (R1-R5)	5	11	Low	✗	✗	✓	✓	✓	–		
		Classroom (C1-C2)	2	–	–	✗	✗	✓	✗	✓			

- The economic status, cooking medium, available ventilation, and air conditioning options in different sites in four deployment regions
- We releases **89.1M** samples, totaling **13646 hours of air quality data** and **3957 activity** annotations from 24 participants among 46 occupants

Indoor Pollution Dynamics

- **Activities of Daily Living & More …**
  - Lesson learned from activity annotations
- Due to Indoor Ventilation
- Due to Indoor Airflow Dynamics
- Floor plan and Room Structure





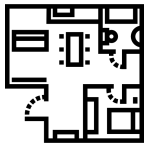
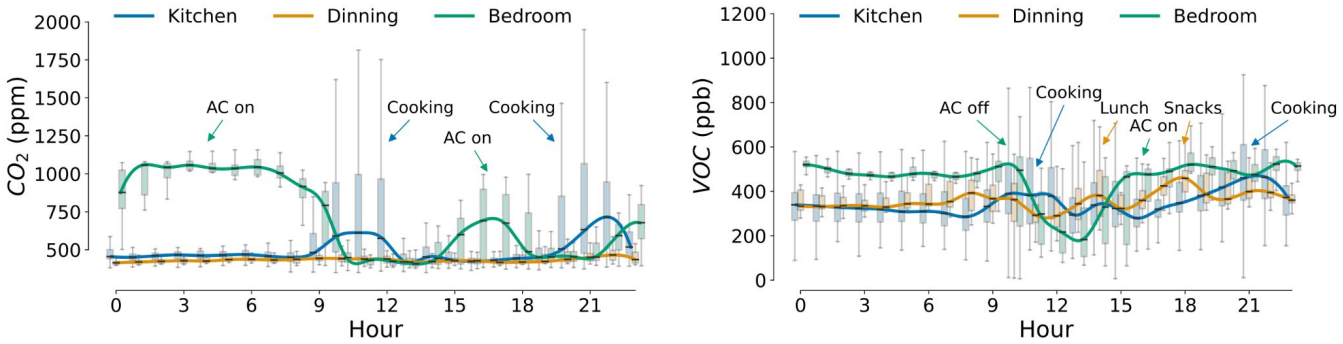


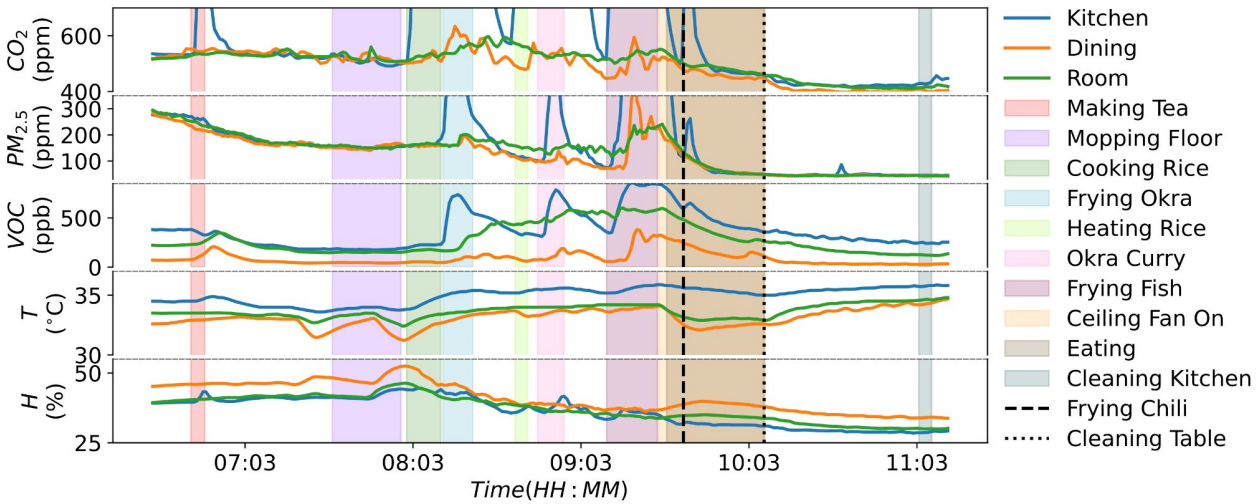

Image sources: https://www.flaticon.com/

Activities of Daily Living (ADL)



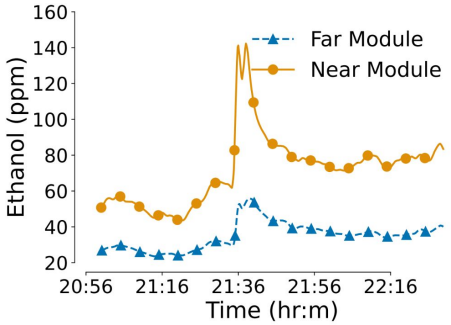
- Pollution centrations are significantly **different** across the **kitchen**, **dining**, and **bedroom** for different hours of the day based on occupant's **activities**
- Example: In the **kitchen**, CO_2 is emitted during **cooking**
- Example: In the **bedroom**, the median CO_2 levels are high during the **night**

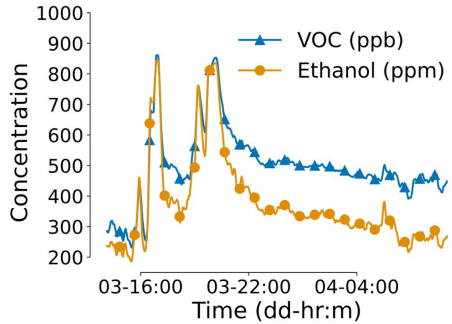
Activities of Daily Living (ADL)



- CO_2, $PM_{2.5}$, and VOC concentration in the kitchen, adjacent bedroom, and dining
- Pollution for typical morning activities like cleaning and cooking:
  - **Long-term frying** significantly elevates **$PM_{2.5}$** and **VOC** levels that **spread to nearby rooms**
  - In **boiling**, **heating**, or **short-term frying**, pollutants remain **contained near** the **source**
  - **Cleaning** and **mopping** activities increase the relative **humidity**

Pollution Sources Generated due to ADL





Fruit scraps

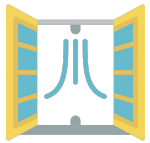
- **Increase in Ethanol** (C_2H_5OH) concentration at the nearby sensing modules when the user **cuts fruits** at the dining table
- The nearest sensor experiences a higher exposure

Food Residuals

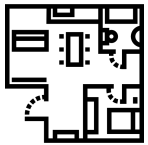
- Shows measurements from a kitchen during the night hours
- The excess **food residuals** and **dirty dishes** in the kitchen sink cause **elevated levels** of **VOC** and **Ethanol**
- Pollutants **spread** until the kitchen is cleaned up the **next day**

Indoor Pollution Dynamics

- Activities of Daily Living & More …
- **Due to Indoor Ventilation**
  - Lesson from kitchen
- Due to Indoor Airflow Dynamics
- Floor plan and Room Structure





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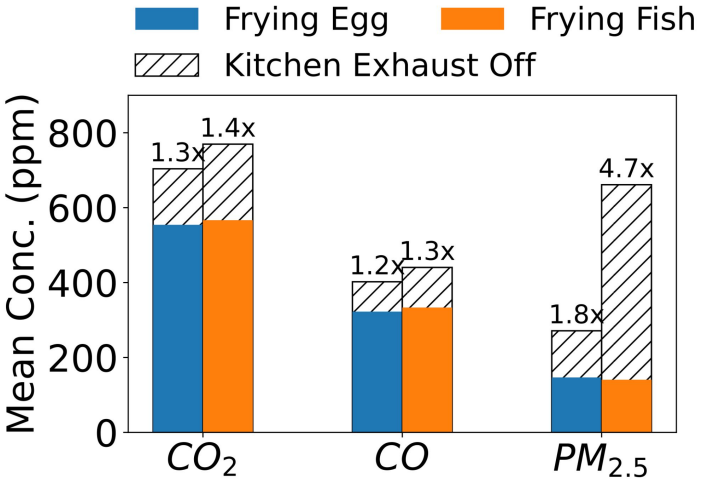
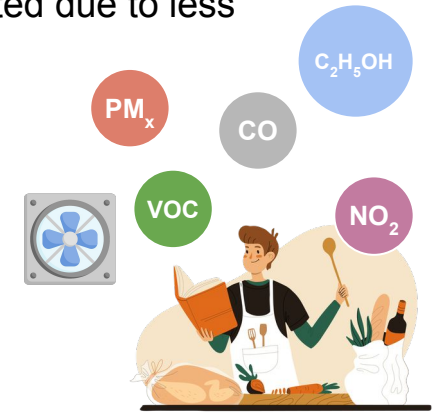
Ventilation in Kitchen



- The pollutants **increase** when exhaust fan is off
- Mean **$PM_{2.5}$** increase **4.7x** for frying if **exhaust is off**
- PM_x, CO_2, CO are most impacted due to less ventilation



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Indoor Pollution Dynamics

- ❑ Activities of Daily Living & More … ✓
- ❑ Due to Indoor Ventilation ✓
- ❑ **Due to Indoor Airflow Dynamics**
  - ❑ Lesson from swirling airflow
- ❑ Floor plan and Room Structure

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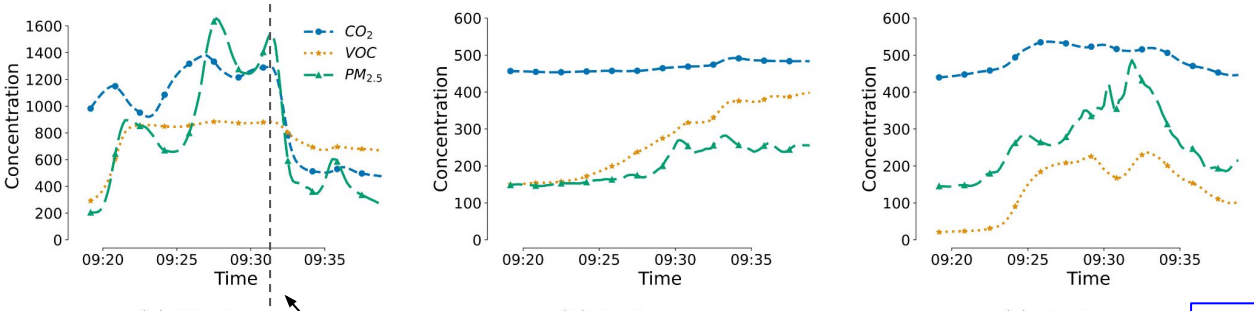
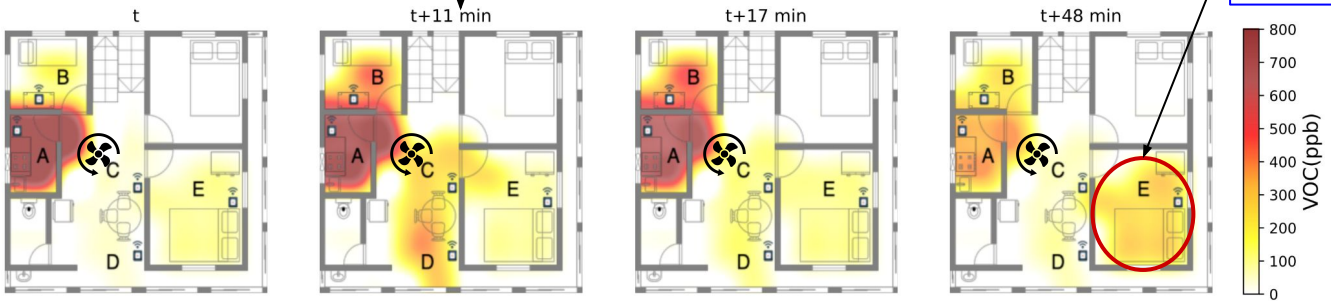
Swirling Airflow due to Ceiling Fan



(a) Kitchen (b) Bedroom (c) Dining

Cooking ended

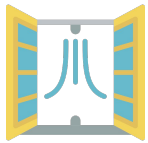
Pollutant trapped in bedroom (E)



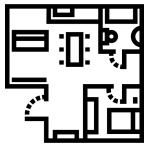
Cooking Starts **Spread** **Deplete** **Trap in (E)**

Indoor Pollution Dynamics

- ❑ Activities of Daily Living & More … ✔
- ❑ Due to Indoor Ventilation ✔
- ❑ Due to Indoor Airflow Dynamics ✔
- ❑ **Floor plan and Room Structure**
  - ❑ Lesson from household with isolated kitchen





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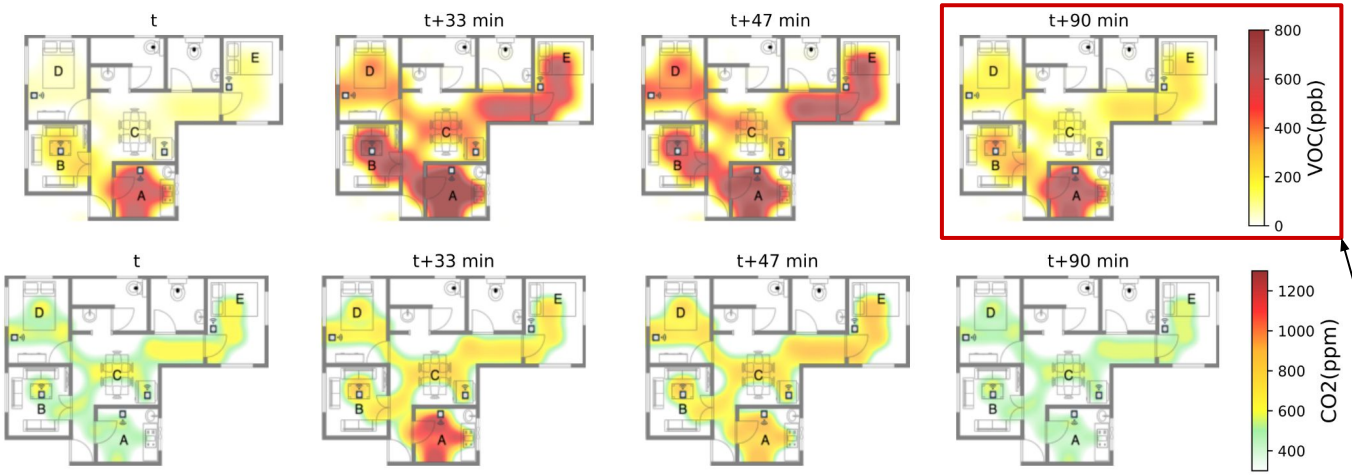
Floor plan with Isolated Kitchen

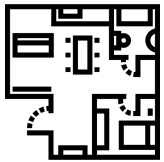


Pollutants get trapped in Bedroom (B, E)

- Cooking starts at t and ends at t+33 min
- VOC **gets trapped** due to the isolated room structure even after 14 mins
- CO2 normalizes **57 mins** later at t+90 min when VOC **persists** in the kitchen (A) and the living room (B)

Key Findings from the Dataset

- Occupants' **behaviour and activities** influence indoor air quality
- Airflow **directs the spread** of pollutants in indoor environments
- An **isolated rooms** can lead to **trapped** and **long-term lingering** of pollutants
- Some pollutants such as **VOC**, **Ethanol** are **aggressive** in **spreading** and **hard** to **ventilate**, irrespective of the floor plan and room structures



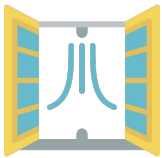


Image sources: https://www.flaticon.com/

Possible Applications of the Dataset

- Pollution Source Identification and Activity Monitoring **[1]**
  Occupant's activities generate specific pollution patterns based on the activity and how it is performed. The dataset records many such instances, which can be used to learn these unique relationships and develop models for source detection and activity classification.

- Analysis of Spreading and Accumulation Patterns in Different Floor Plans **[2]**
  The dataset can be used to analyze the spreading, accumulation, and trapping behavior of indoor pollutants in different indoor floor plans.

- Healthy Home Characterization and Improving Designs of Modern Indoors
  The dataset can be used to identify contributory features and design choices of a household that help cope with pollution accumulation and spread, characterizing the healthiness of the household.

- Smart Device Control for AC, Exhaust, Air Purifiers
  The dataset can be used to design intelligent control policies to modulate indoor ventilation through precise actuation of exhaust fans, air conditioners, and air purifiers to improve indoor air.

[1] Exploring Indoor Air Quality Dynamics in Developing Nations: A Perspective from India. In ACM JCSS 2024
[2] Exploiting Air Quality Monitors to Perform Indoor Surveillance: Academic Setting. In ACM MobileHCI 2024 (Late-Breaking Work)

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Lab Page: Ubiquitous Networked Systems Lab https://ubinet-iitkgp.github.io/ubinet/

Personal Page: https://prasenjit52282.github.io/

Thank You!

Scan the QR to know more about this work!

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