Air Quality Monitoring

Background/Motivation

Air Quality can be measured using the Air Quality Index (AQI). AQI measures particles and gas pollutants in air. Poor air quality can cause lung and heart diseases, amongst a host of other fatal conditions. It is the 5th largest killer in India, with 620,000 people dying because of diseases related to air pollution. Air Quality is a very necessary metric to measure, just like Temperature and Noise, so that organizations can take concrete actions to prevent poor air quality, with the help of our neighbourhoods and communities.

Karnataka State Pollution Control Board (KSPCB) is the official government body that monitors air quality in the city. There are a total of 24 air-monitoring stations, each of which cost 1 crore INR. None of the monitoring stations offer real-time updates, though the website does give a monthly average update. Our project is an effort to make air quality data more accessible, accurate, and localized – which could lead to very impactful outcomes, as detailed below.

To enable community-driven data collection that is easily accessible (especially to the community itself), Reap Benefit has launched a DIY and cost-effective air quality monitor called Breathe. Following this, we have mapped data in Bangalore, Chennai, and Delhi. We have also held various air pollution awareness campaigns, where we reflect on daily actions that impact the quality of air around us. We do this by showing physical proof of the drastic change in air quality—such as lighting up an agarbatti (incense stick), dusting off a mattress, or just taking a carpool for the day. We have also had several Deepavali campaigns where we focus on the terrible impact of crackers on air quality.

Goals/Objectives

Currently, air quality monitoring is an expensive government initiative, data from which is not available to the general public in real-time. Our objective is to provide easily accessible, comprehensive, and real-time air quality data via cost-effective means. The air quality data will be made easily accessible through our website and web application, such that communities can monitor it and take required action. The data will be comprehensive and real-time as it will be collected by a large network of moving cabs, which will have GPS and Wi-Fi enabled monitoring devices. Currently, the devices cost Rs. 5000 (without power source and GPS), which is very cost-effective when compared to the current expenditure on air quality monitoring stations.

Using this data, we will have civic-engagement drives, to make communities understand the importance of air quality, and push them towards working on improving the locality's air quality. We will also use this data to hold government authorities accountable, and help them in their efforts to monitor and improve air quality.

Primary Investigation done to understand why people do not understand the impact of Air Quality on their everyday lives
1. Lack of awareness: Many people are simply unaware of the concept of air quality and its impact on their health and the environment.
2. Complexity of the issue: Air quality is a complex issue that involves a variety of factors, including sources of pollution, weather patterns, and topography. It can be difficult for people to understand how all these factors interact to affect air quality.
3. Inadequate education: Education on air quality is often limited or non-existent in schools and communities. This means people do not have access to information and resources to understand the issues.
4. Misinformation: There is a lot of misinformation about air quality, including myths about the causes and effects of pollution. This can confuse people and make it harder to understand the real issues.

5. Lack of transparency: Air quality data is often difficult to access and interpret, making it hard for people to understand the severity of the problem in their area.
6. Conflicting interests: There are often conflicting interests between industry and government when it comes to air quality. This can create confusion about the causes and solutions to air pollution.
7. Geographic disparities: Air quality can vary greatly depending on where you live. Some people may live in areas with very high levels of pollution, while others may live in relatively clean areas. This can make it hard for people to understand the severity of the problem.
8. Lack of personal connection: Because air quality is often invisible, people may not feel a personal connection to the issue. This can make it less of a priority in their minds.
9. Psychological barriers: People may feel overwhelmed or powerless when it comes to air quality issues. This can lead to apathy or denial.
10. Political polarization: Air quality issues can become politicized, with different political parties taking different stances on pollution and environmental regulations. This can make it harder for people to understand the real issues and make informed decisions.

Solution

We built 2 types of devices
1. Portable AQMs - Raspberry pi based AQMs, which could constantly log the values on their internal SD card. These were reliable to record data on SD cards, but we faced issues syncing this offline data to a remote server. These paired with the
2. Fixed AQMs - NodeMCU based AQMs
   a. ESP8266 is a single core wifi enabled microcontroller – this has been most reliable in transmitting data. However, it struggles to reconnect on power outages without help
   b. ESP32 – dual core wifi and Bluetooth enabled microcontroller – this is a new variant and we are testing and improving its reliability.

The data was being pushed to a google sheet to make it more accessible to users who would want to analyse it.

Activities

We got a set of 11 interns to engage people in multiple locations to engage citizens around understanding air quality. The below table shows people engaged, and learning outcomes as described by them.

Name	No of people	Learning Outcomes
Bhavya Verma	49	During this program I came out of my comfort zone and it helped me to gain confidence to interact with new people in public places. After interacting with people I got to know their knowledge and perspective about air quality which also helped me to know more about it. I also got to Learn about how air quality machines work and what is the difference from the devices used by the government. Through this awareness campaign we have made a good progress in educating people about the air quality
Angelyn Varghese	50	Throughout the course of working with the ngo, it helped me get an in depth knowledge about how unaware people are about aspects of their daily lives and how it impacts them. I also learned that sometimes to make headway in your own life, we need to take a look and work towards the greater good. It made me want to collaborate more and work for a common goal of improving life conditions for ourselves as well as the community. While I got educated on the lives of people, it also taught me practical information

		about air quality and pollution and what we as society can do our small way to improve it.
Yamini Dhavala	56	We learnt that different people respond to different types of marketing measures. Partnering up with this NGO gave us an opportunity to conduct an awareness drive which also helped us step out of our comfort zone. Apart from learning and spreading awareness about air quality, we also experienced segments of marketing and sales through this drive. Air quality measuring devices are not economically feasible, however, on the contrary, the devices we used were. From this we see a real life example of how innovation and technology can help improve the environment.
Eshan Ghose	53	I realised a lot of people are actually not aware of the pollution levels in different places, even though they are aware of ways to reduce pollution. Thus, they don't have incentive to take the necessary measures. In this scenario, our campaigns to raise awareness about the levels of air quality, pollution in different areas and its effects on people in the long term helped and intrigued the audience. I am confident that although there is good progress, we still have a long way to go before we achieve air quality levels of first world countries. I learnt to talk to people, to get my point across while being to the point, precise and accurate, while making the presentation interesting to capture the attention of the audience.
Yash Manani		Conversational abilities were one of the first hand learning outcomes that came out of this project, other techniques like the guess game and more questioning to grab attention is one of the things i learnt. I also learnt about the level of awareness regarding the environment in campus and around us in the city. The working of the aqm device, and how levels differ from places, timings and even the fact that a few metres could make a huge difference in the readings.
Ishita Jain	59	How to approach different people and getting their attention to what we were talking about, How the air quality measurement device measures the quality, how the air quality differs during the entire day(i.e. early in the morning when roads are empty, the quality is between range 0-30 but as soon as the traffic increases during the day, the numbers increase)
Khushi Sharma	49	I actually learned how the device works, and something as small as that device can inform us about something so serious as the air quality. Talking to different kinds of people also helped me gain perspective as to the rise in pollution levels and what we can do as a community to reduce it.
Tamanna Patel		I gained deeper knowledge about air quality and its consequences on the environment. Furthermore, i learned that it is quite crucial to raise awareness regarding this problem and how to combat it to make our future better.
Shaurya Goel	55	I was considerably surprised by the impact of smoking on the environment, this made me aware about the extent of its ill effects. This project honed my soft skills and improved my confidence in speaking to random people and conveying important information in an understandable manner. This has led to my personal development and growth to a great extent
Aryan singh	53	I learned about the impact of air pollution on health and how technology can be used to monitor and address the issue. I also gained valuable skills in communication, collaboration, and data collection.
Shivani Choudhary	56	Other then the learning aspect I gained for myself, I was very happy with the impact I could pull off on the peoples faces and expand their insights and

		develop understanding regarding the same. It was a new experience for the localities.

Learnings post prototyping and citizen engagement

Technical Learnings

1. Pick the right controller for the use case
   a. It is important to understand the difference between a microcontroller and microprocessor to start with. A Microcontroller is a CPU to choose where the task is fixed, and you need something which consumes less power. It cannot run an OS. Just the instructions for the tasks you need. A microprocessor runs an OS, and consumes more power, and can make complex decisions and execute more than just your instructions.
   b. NodeMCU boards based on ESP32 or ESP8266 are Microcontrollers
   c. Raspberry Pi boards are based on ARM microprocessors and need the Linux OS to run.
   d. For fixed AQMs, which were in a fixed location, we realised it is best to use a NodeMCU board.
   e. For Movable air quality monitors, due to the complexity of the use case - a portable computer like a Raspberry Pi is better. The Raspberry Pi has an SD card which contains the OS and programs and data. This is very useful to store AQM data while you are on the move. However, reliably transferring data as soon as you get WiFi connectivity has been a challenge we are working to solve.
2. Pick the right dust sensor
   a. There are 2 types of dust sensor – Active and Passive. Active dust sensors have a fan to ensure a constant flow of air.
   b. Position it right – active dust sensors work best in a flat horizontal placement – this ensures minimum variation in values
3. Ensure that nothing creates a back flow by blocking the sensor fan vent – this disturbs the values
4. Materials for casing
   a. We started off using MDF boards – which are wood boards made by compression sticking wood powder together. After half a year of exposure to moisture and humidity, and regular removal for cleaning, we noticed that it started to come apart. For this, we now recommend a mix of Acrylic and MDF in the box design.
5. Reading datetime with GPS and without
   a. The GPS module is able to get the date-timestamp as part of its operation in GMT time zone. We need to access this and upload the data in IST.
   b. If there is no signal, but you have wifi access, there is a software library which will allow you to sync with the NTP servers. NTP servers are like highly accurate clocks on the internet that help all devices agree on the correct time. They provide a reference time that devices can synchronize with, ensuring that everyone's clocks are set correctly. Just as a clock tells you the time, an NTP server tells your device the time, ensuring coordination and accuracy across the digital world.
6. Affordable air quality monitors are not always accurate. They are indicative and have an error of 5-10%. Honeywell's dust sensors are factory certified to have this error margin.
7. Quality of air quality readings increases with 2 sensors detecting the same air sample one after the other at the same moment and an average being taken of both their readings. However, we are yet to experiment deeply on this.
8. Also they have lesser hours of validation or ruggedity built into them, which is a pro in the sense that it makes it easy for the viewer to feel they too can build it, but a con that it doesn't feel like it's a product. The decision we have to make is whether we want to own the DIY-education space or the Product-impact space.
9. Portable air quality monitors used to engage people should not be designed to transmit data. Typically, we use ESP32 or ESP8266 as the microcontroller of choice. These have a WIFI component built into them. Hence, we become dependent on either a dongle, or as

more often the case, This will increase cost and complexity of design as it will have to factor in cost of a SIM module to send data, and not rely on the user/owner's phone for WIFI hotspot.

10. Low cost GPS modules are unreliable to get location accurately and consistently. We experimented with multiple batches of Neo6M GPS module and found the ones with the model number ending 001 more accurate than the ones ending 0001.

Engagement

1. People look for expertise of the presenter due to massive amounts of misinformation and disinformation, unless it is made into a game or an experience
2. Having a real time air quality monitor in hand allows to break this perception that air quality is a complex topic and catches the curiosity of the viewer
3. Engaging interns to engage citizens increases outreach, but can reduce quality of outreach. However the goal of getting more people to become curious about air quality can be met.
4. Designing guess games worked best for adults and experiences to understand air quality worked best for youth

Data Quality

a. Data fields – it's best if these values are collected from aqms
    a. Sensor readings –
        i. PM2.5 – records PM2.5 value
        ii. PM10 – if the sensor records this, great. Note – the Pollution Board doesn't recognise this value. They only recognise PM2.5 in the law
    b. Other Data points
        i. Date Time stamp of the reading so that the database doesn't put in the value when this information is being written in. This is very useful when you have a portable AQM, where the device records date-time. When it is ingested as a bulk file into the database, it is true – as in, when the reading is taken and not the time of the data being ingested into the database.
        ii. Device Name or Device ID – to recognise contributor so that in case where there are multiple values across different time stamps come, it allow
        iii. If the device name indicates the type of AQM – fixed or portable, this field can be discarded. Else, this is important.

Challenges:

With the Ukraine war, the cost of components increased 3x, making the entirety of the proposal impossible. The Raspberry pi increased from Rs 1,400 to ~Rs 4,000. The dust sensor increased from Rs 2,600 when budgeted to Rs 6,000 when we needed to procure materials. As a result, the cost would go beyond the Rs 5,000 we had budgeted for each AQM.

We had received an old batch of Dust sensors as a donation, and have used them for now, and will build even more AQMs once the costs are reduced.

The money was shifted to cover costs of human resources to do more experimentation and creating the repository of activities and knowledge.

As a result of the above, these are the outputs we can offer to the larger community.
1. DIY AQM – how to build it and program it (link to forum to be posted)

Air Quality Curriculum

Event Plan: Introduction and Demo of Air Quality Monitor to walk in visitors

Duration: 20 minutes (including Q&A)
1. Welcome and Introduction (2 minutes)
    ●   Greet the attendees and thank them for visiting the stall/stopping to speak to you.
    ●   Briefly introduce yourself and the purpose of this engagement (introduce them to Air quality, its impact on them, the AQM etc).
    ●   Tell them to hold all questions to the end where they can clear all their doubts
2. Importance of Air Quality (3 minutes)
    ●   Discuss the significance of monitoring air quality for health and well-being
    ●   Highlight the adverse effects of poor air quality on individuals and the environment (Obama loosing 7 minutes of his life In his visit to Delhi is a great fun fact to share).
3. Introduction to the Air Quality Monitor (2 minutes)
    ●   Introduce the air quality monitor and its key features – explain how the dust sensor works and how this is low cost.
    ●   Explain need for low cost sensors every square kilometre so that it is easy to detect air quality patterns and how the government has a very less number of AQMs (please refer to your states Pollution control board's data to see how many AQMs it has)
    ●   Explain how it measures dust and can provide real-time data.
    ●   Explain how real time data can be used
4. Demonstration of the Air Quality Monitor (10 minutes)
    ●   Conduct a live demonstration of the air quality monitor.
    ●   Show how to set it up and operate it effectively.
    ●   Explain the different readings and their implications.
    ●   Highlight any unique functionalities or benefits of the monitor.
5. Q&A Session (3 minutes)
    ●   Allow the audience to ask questions.
    ●   Answer inquiries about the air quality monitor, its usage, and any related topics.
6. Closing Remarks (1 minute)
    ●   Thank the attendees for their participation.
    ●   Encourage them to explore the topic further and seek additional information if needed.

Event Plan: Introduction, Demo, and DIY Air Quality Monitor Workshop
Duration: 2 hours (including Q&A and DIY activity)
1. Welcome and Introduction (5 minutes)
    ●   Greet the attendees and express gratitude for their presence.
    ●   Provide a brief overview of the event's objectives and schedule.
    ●   Tell them to hold all questions to the end where they can clear all their doubts
2. Importance of Air Quality (10 minutes)
    ●   Discuss the significance of monitoring air quality for health and well-being
    ●   Highlight the adverse effects of poor air quality on individuals and the environment (Obama loosing 7 minutes of his life In his visit to Delhi is a great fun fact to share).
3. Introduction to the Air Quality Monitor (15 minutes)
    ●   Introduce the air quality monitor and its key features – explain how the dust sensor works and how this is low cost.
    ●   Explain need for low cost sensors every square kilometre so that it is easy to detect air quality patterns and how the government has a very less number of AQMs (please refer to your states Pollution control board's data to see how many AQMs it has)
    ●   Explain how it measures dust and can provide real-time data.
    ●   Explain how real time data can be used
    ●   Share the benefits of using a DIY air quality monitor.
4. Demonstration of the Air Quality Monitor (15 minutes)
   ●   Conduct a live demonstration of the air quality monitor.

- Show how to set it up and operate it effectively.
- Explain the different readings and their implications.
- Highlight any unique functionalities or benefits of the monitor.

5. Q&A Session (10 minutes)
    - Open the floor for questions from the audience.
    - Answer inquiries about the air quality monitor, its usage, and any related topics.
6. DIY Air Quality Monitor Workshop (1 hour)
    - Provide all the necessary components and tools for building the monitor.
    - Divide the attendees into small groups or pairs for a hands-on activity.
    - Guide them through the step-by-step process of assembling the monitor.
    - Offer assistance and clarification as needed.
7. Testing and Calibration (15 minutes)
    - Instruct the participants on how to test and calibrate their DIY air quality monitors.
    - Provide guidance on proper usage and placement of the device.
8. Q&A and Sharing Session (10 minutes)
    - Allow participants to ask questions about the DIY process and troubleshooting.
    - Encourage participants to share their experiences and insights.
9. Closing Remarks (5 minutes)
    - Thank the attendees for their active participation.
    - Recap the key points covered during the event.
    - Provide additional resources or references for further exploration.

Other Activity Ideas:
1. Guessing game - If the venue is a mall or college, measure the AQ in multiple places like all floors, classrooms vs toilets vs passages vs shops/offices, basements, gardens, roof etc. When you stop and speak to any person, make them guess where the air is most polluted or state the place and ask them to guess the air quality after seeing the air quality where you are speaking to them (being able to see AQ in the place where you are speaking to them will make their guesses calibrated and more realistic).
2. See to Believe – use the sensor to see the impact of daily activities like running a vehicle in idle to see the change in AQ, or dusting the floor or door mat, being in dusty environs without tree cover, light an agarbathi or cigarette (if you use cigarette, it can also be used to highlight the impact on health to inhale that dust into your lungs), burn paper, cook etc. Remember to highlight the duration of the change in AQ so that they understand the power of air flowing through the region.

Latest iteration of the offline AQM designed to engage viewers - All components are visible to indicate the simplicity and to focus on the Dust Sensor, and speak about its accuracy.
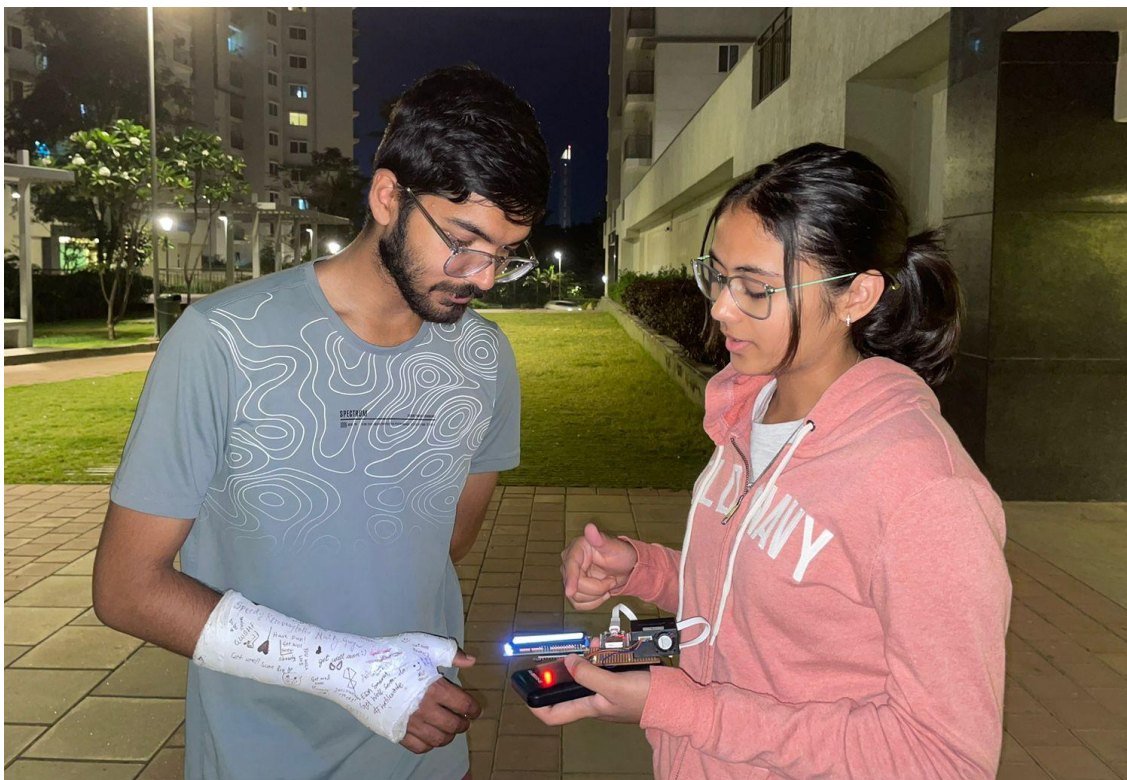
One on One engagement by the volunteers in the early days to build confidence about their knowledge and to understand what kind of questions they could anticipate.

Engaging groups in Public spaces - diverse age groups were engaged to understand what they asked and took as take-aways

Iterating and Playing the guessing game (as mentioned in the activity) in Vega City Mall