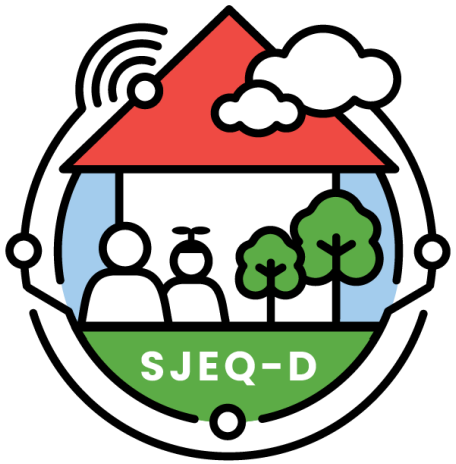
Social Justice and Environmental Quality in Denver (SJEQ-D):

Well-being and Air Pollution Exposure During Major Construction in an Environmental Justice Community



2023 SJEQ-D Advisory Board Meeting

May 17, 2023

University of Colorado Boulder

Denver

CU IN THE CITY

NSF

Meeting Agenda

9:00 - 9:10 Introductions and SJEQ-D Study Overview (10 min)

9:10 - 9:25 Environmental Engineering Team Tasks and Updates (15 min)

9:25 - 9:35 *Discussion (10 min)*

9:35 - 9:50 Social Science Team Tasks and Progress Update (15 min)

9:50 - 10:00 *Discussion (10 min)*

10:00 - 10:10 Break (10 min)

10:10 - 10:25 Technology Team Tasks and Progress Update (15 min)

10:25 - 10:35 *Discussion (10 min)*

10:35 - 10:40 NSF Assessment Team Tasks and Progress Update (5 min)

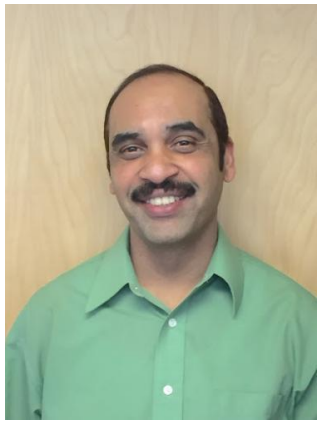
10:40 - 10:45 Education Team Tasks and Progress Update (5 min)

10:45 - 10:55 *Assessment/Education Discussion (10 min)*

10:55 - 11:00 Closing Comments and Next Steps

SJEQ-D Study Team

Environmental Engineering
CU Boulder
PI: Prof. Shelly Miller
Dr. Nicholas Clements
Dr. Sumit Sankhyan
Aniya Khalili
Allison Heckman
Dulce Gonzalez-Beltran
Sophie Castillo



Technology
CU Boulder
PI: Prof. Shivakant Mishra
Omar Hammad
Gopala Kanugo
Rezwan Rahman
Jacob McKinney

NSF Evaluator
CU Boulder
Dr. Daniel Knight

Social Science
CU Denver
PI: Prof. Esther Sullivan
Prof. Marisa Westbrook
Valentina Serrano-Salomon
Jose Puente Puente
La-Doniea Nisbeth
Noemy Perez
Jay Pecenka
Emily Evans

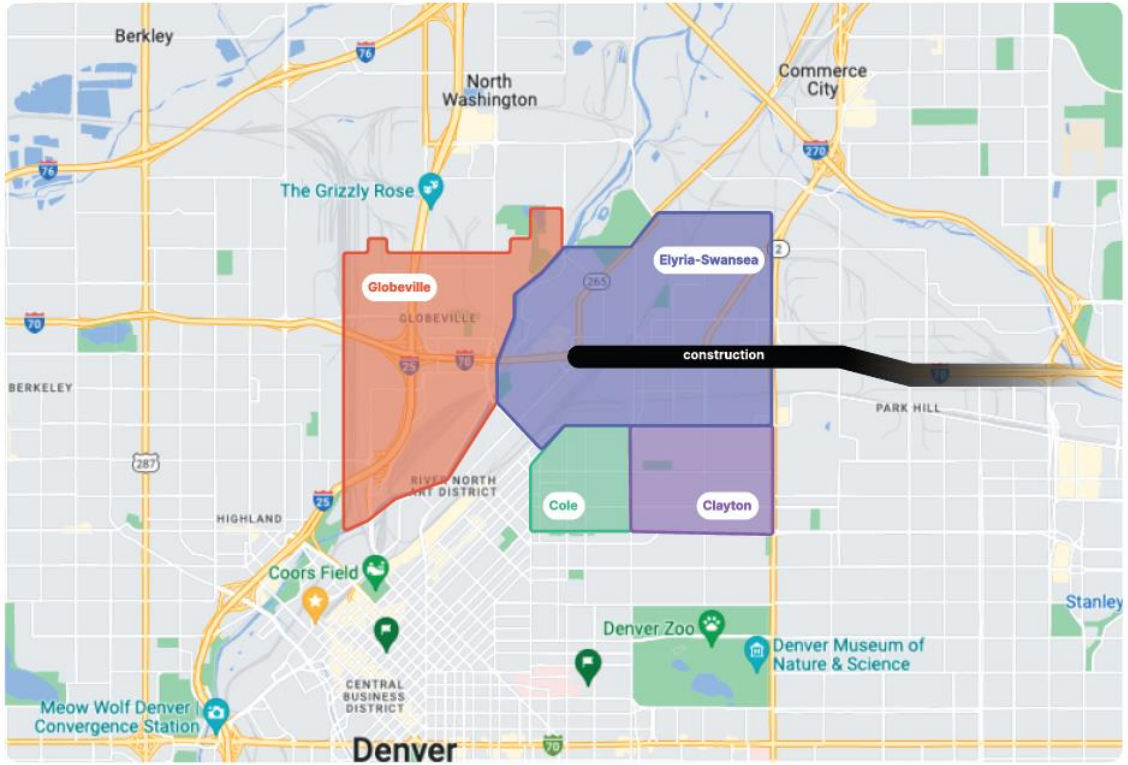
SJEQ-D Study Collaborators

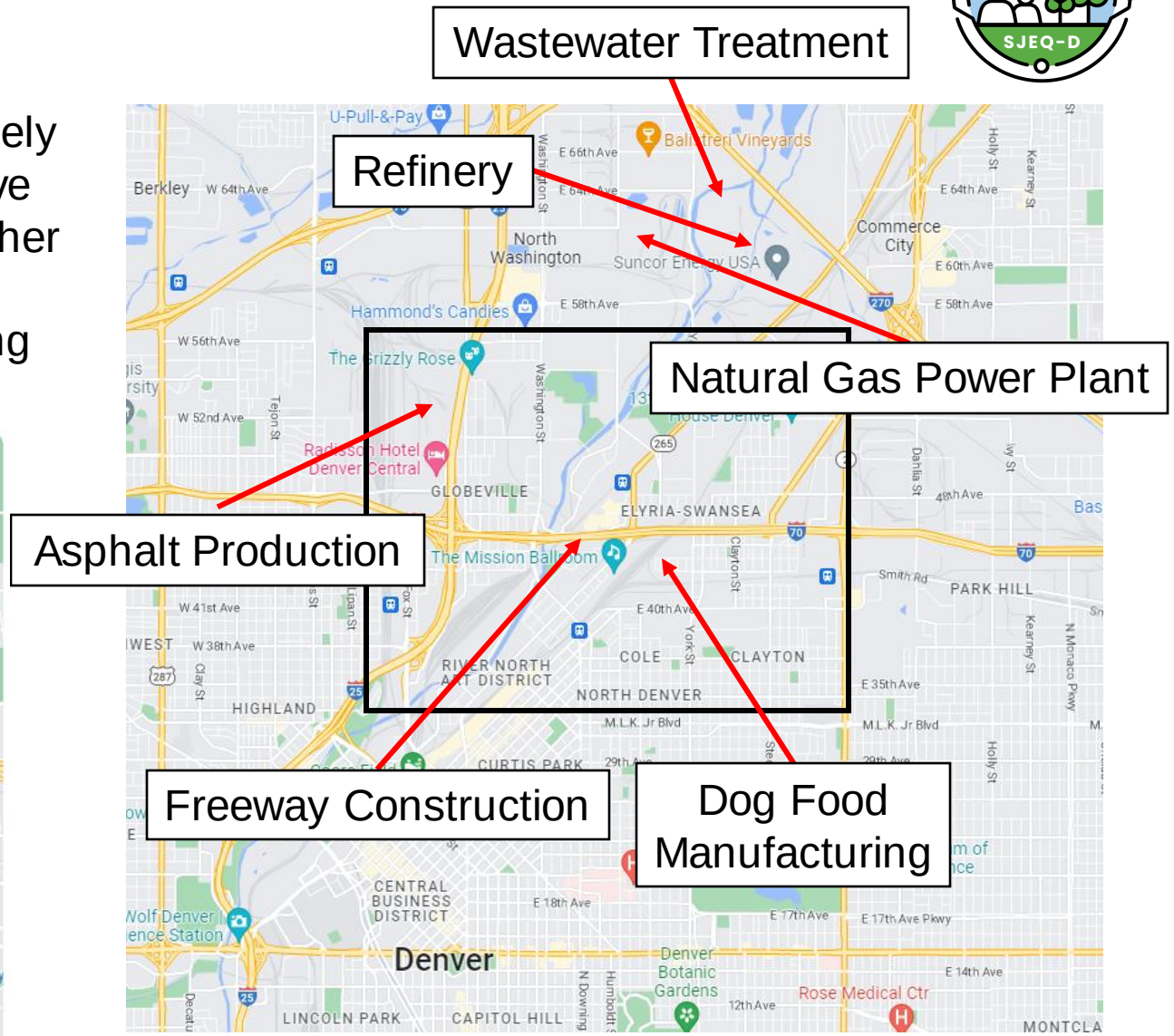
External Outreach and Collaboration

- **Groundwork Denver**
  - Cindy Chang
  - Erika Delzell
  - Rey Gallegos
- Green Latinos
- Growhaus
- Cultivando
- Compost Colorado
- GES Coalition
- Swansea Elementary
- Garden Place Elementary
- DSST Cole School
- Valdez-Perry Library
- Denver DPHE
- Colorado DPHE
- CDOT
- Denver City Council, D9
- CO School of Public Health
- CSU
- Birdseed Collective
- Energy Outreach CO
- CREA Results
- EGS & Partners

Motivation

- North Denver Communities of **Globeville, Elyria-Swansea, Cole, and Clayton** are disproportionately impacted by industrial and traffic pollution and have elevated asthma and COPD rates compared to other regions in Colorado
- Construction in the area (I-70) exacerbates existing environmental injustices



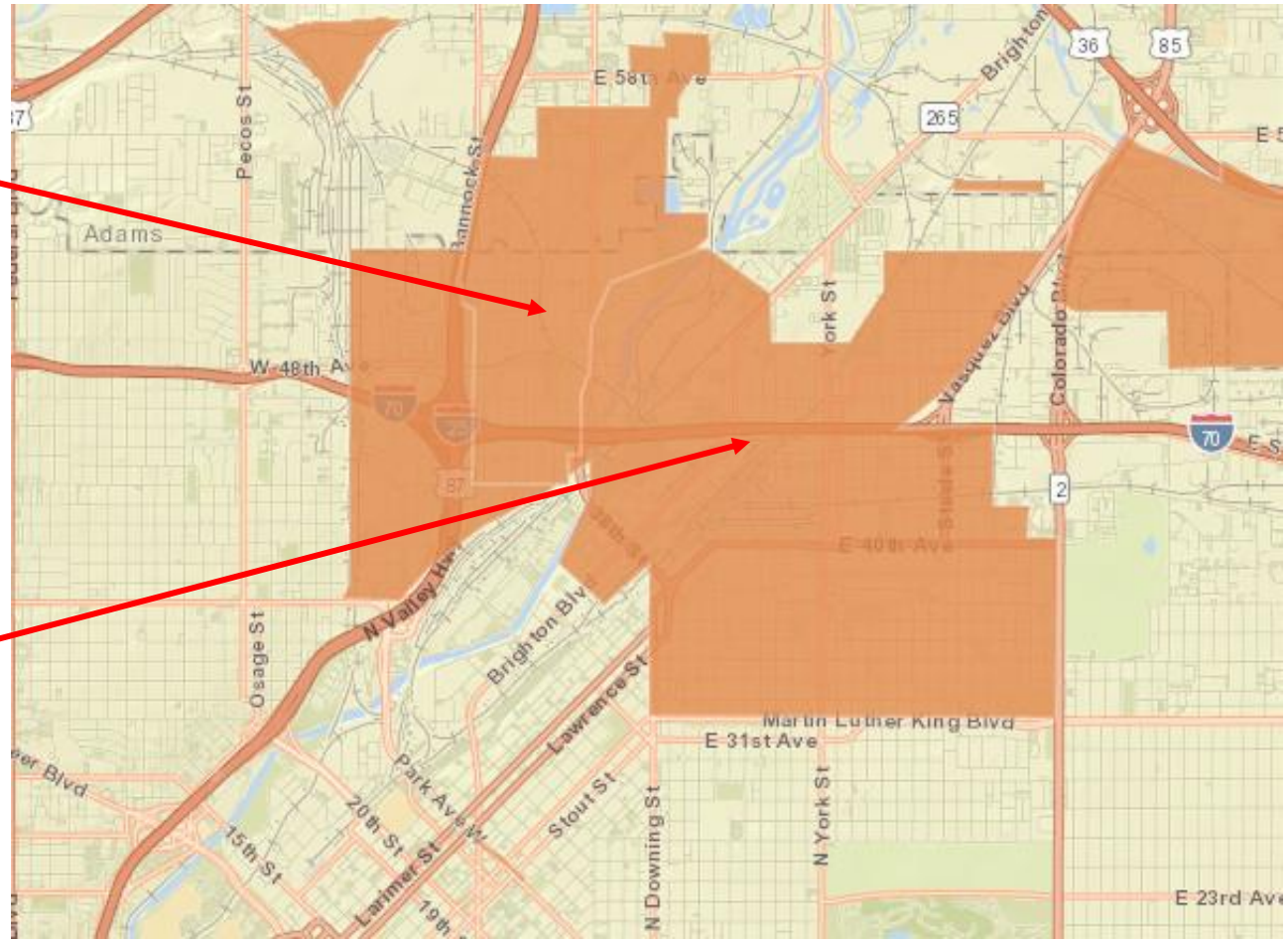


Motivation

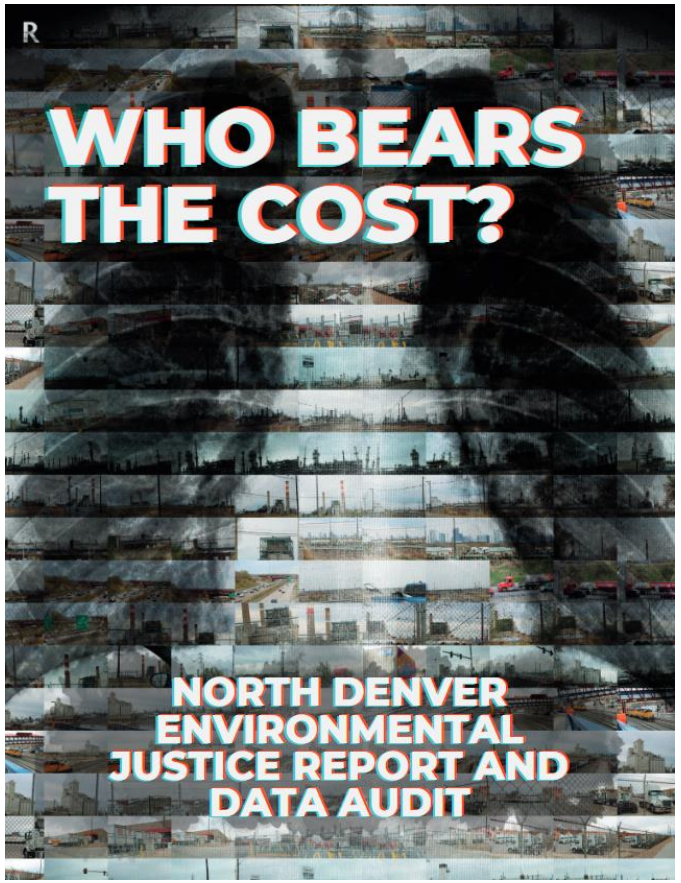
Superfund Sites

CDPHE Colorado Superfund Sites (NPL NRD): ASARCO GLOBEVILLE **SMELTER**

CDPHE Colorado Superfund Sites (NPL NRD): Vasquez/VAS **SMELTER**



Source: [CDPHE]

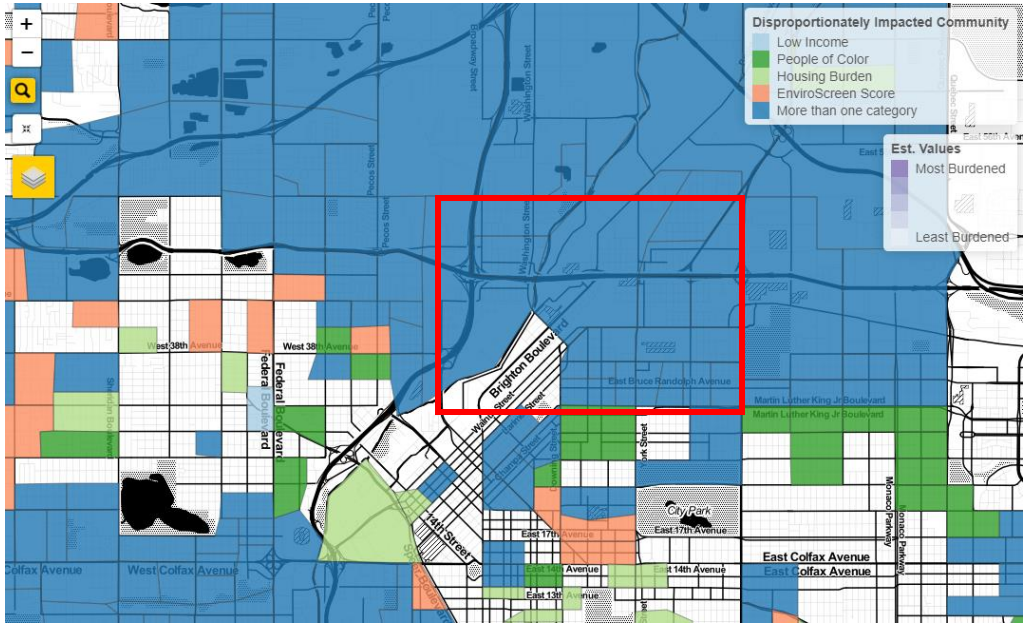


Source: [Green Latinos]

Motivation

In the state of Colorado, the neighborhoods of Globeville, Elyria-Swansea, Cole, and Clayton are categorized as Disproportionately Impacted Communities

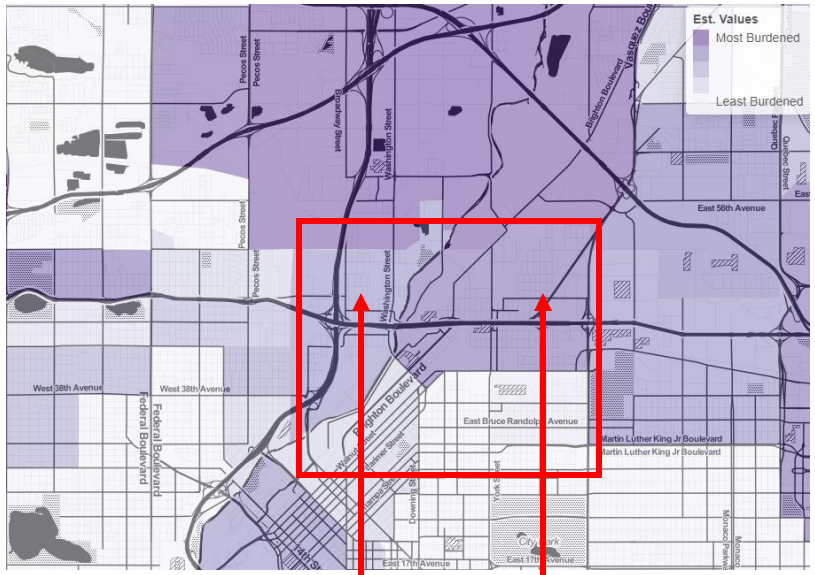
	Globeville	Elyria-Swansea	Cole	Clayton
Over 40% of Households are Low Income	Yes (44%)	No (34%)	Yes (57%)	Yes (50%)
Over 40% of Households are People of Color	Yes (73%)	Yes (69%)	Yes (78%)	Yes (62%)
Over 40% of Households are Housing Burdened	No (30%)	No (34%)	No (25%)	No (22%)
EnviroScreen Score (Percentile) is over 80	Yes (90%)	Yes (92%)	No (77%)	Yes (81%)



Source: [Colorado EnviroScreen]

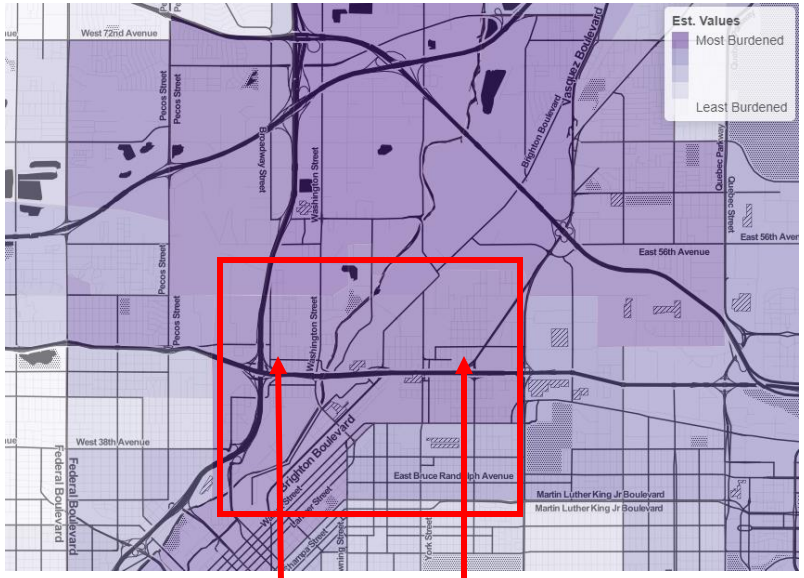
Motivation

Air Toxics



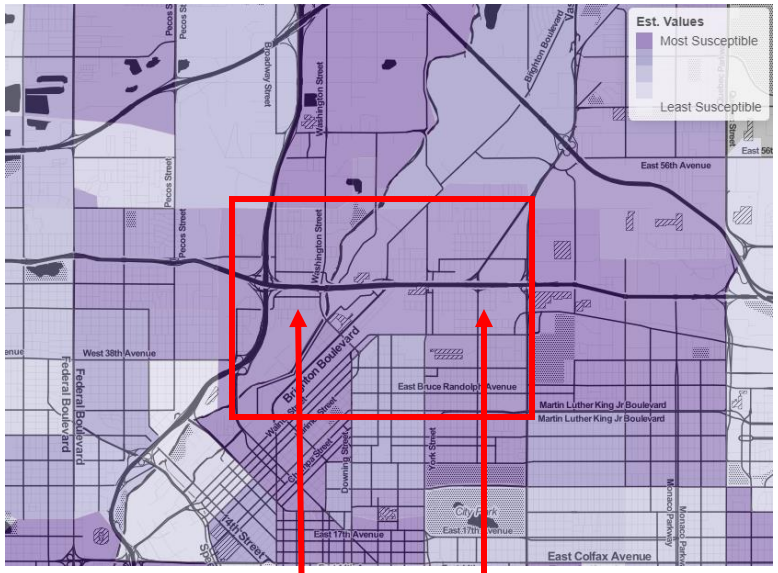
80% 90%

SO_2, NO_x, PM_{10}



94% 96%

Asthma Hospitalization



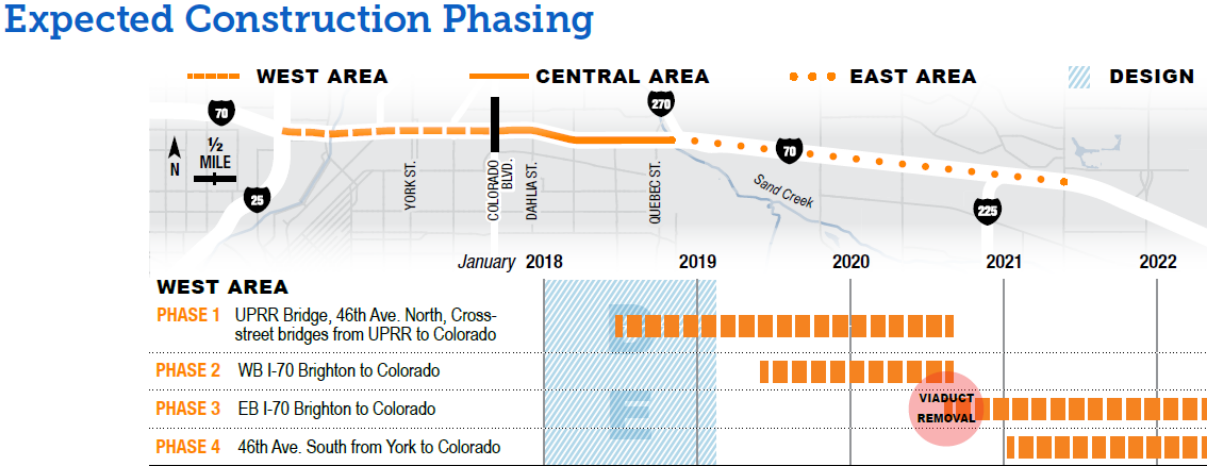
94% 96%

Percentiles for exposure and health outcome categories for Globeville (left) and Elyria-Swansea (right)

Source: Colorado EnviroScreen

Motivation

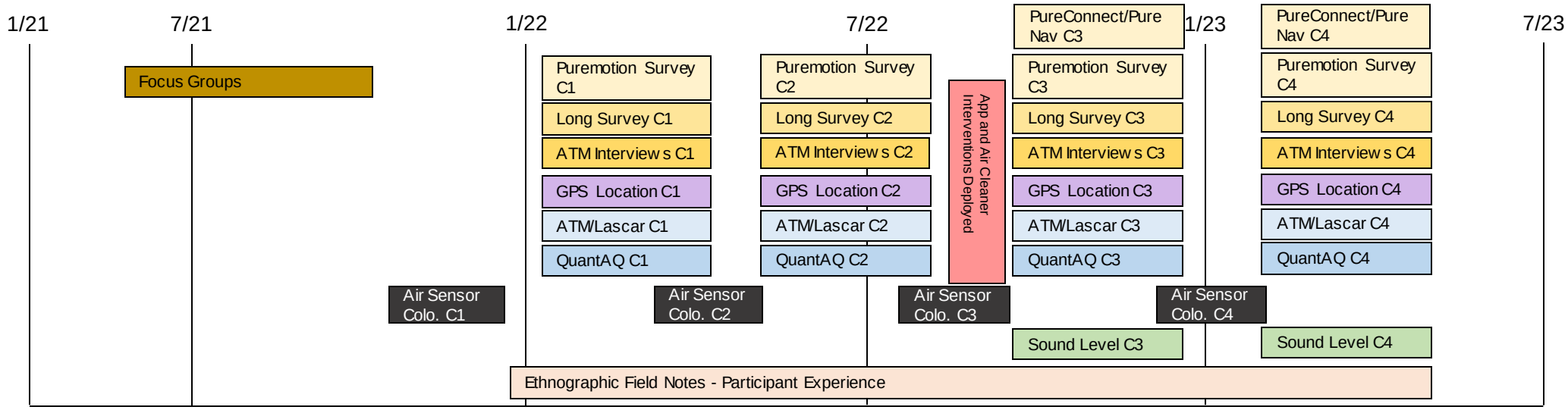
Central I-70 Project



Source: CDOT

SJEQ-D Study Design

https://www.sjeqdenver.com/



Social Science Data Sets

- Focus Groups
- Long Survey
- Atmotube User Interviews
- Ethnographic Field Notes

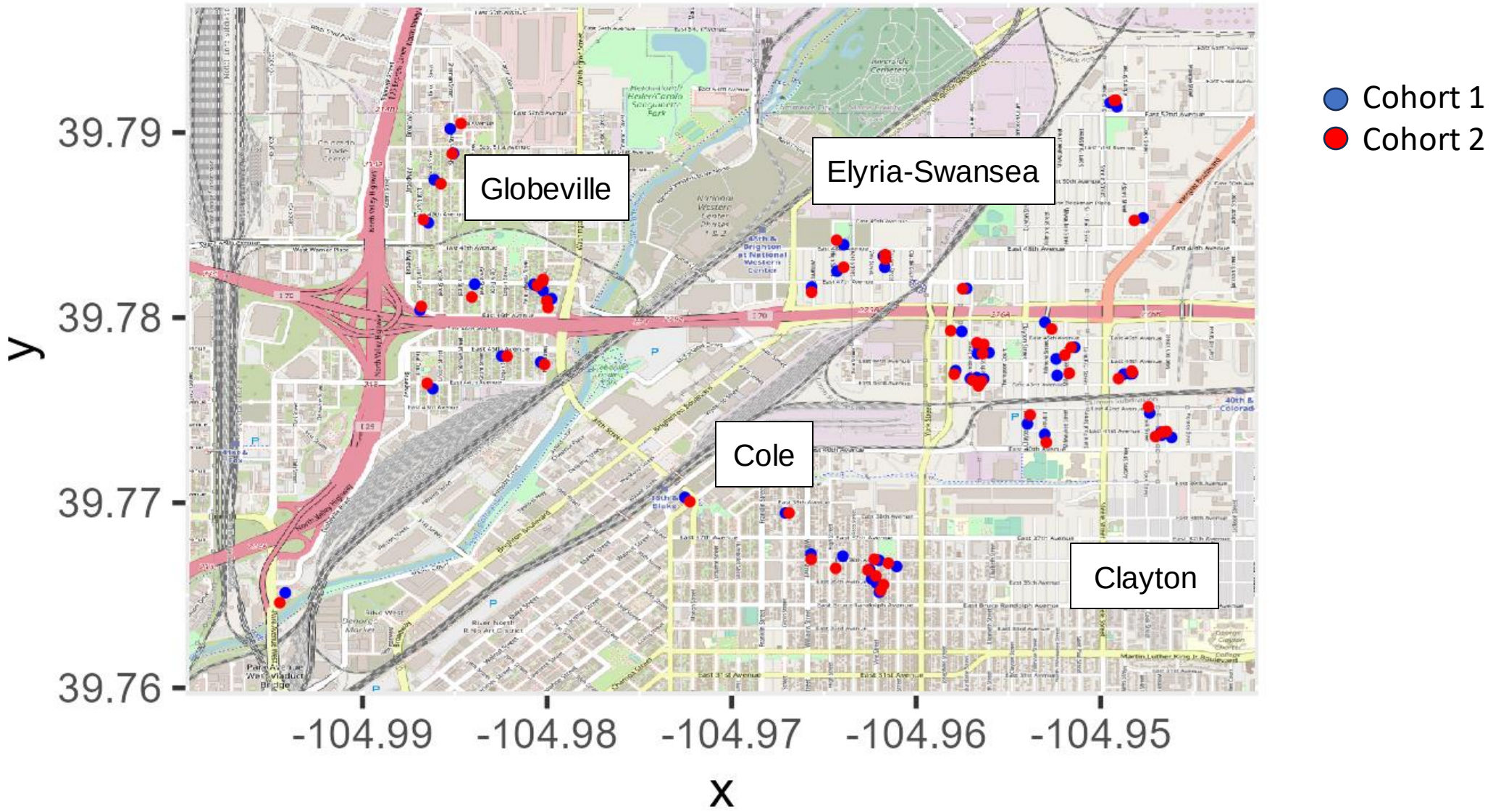
Env. Eng. Data Sets

- Atmotube Personal Exposure Monitoring
- QuantAQ Ambient Monitoring
- Sensor Colocation Testing
- Sound Level Monitoring
- DIY Air Cleaner Intervention

Tech. Data Sets

- Puremotion Surveys (EMA)
- GPS Location Tracking
- PureConnect (Slack) Participant Communication Intervention App
- PureNav (Slack) Trip Planning Intervention App

Participant Spatial Distribution of Cohorts 1 & 2



Note: Points are jittered to anonymize participant home locations

SJEQ-D Environmental Engineering Team: Methods and Findings

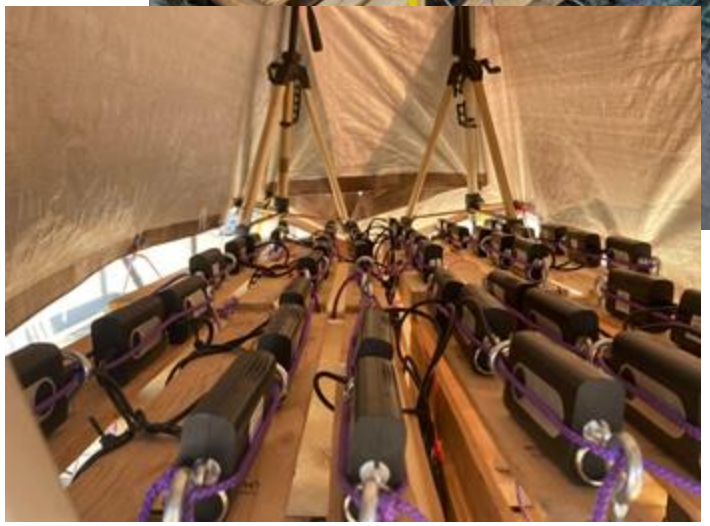
Personal Exposure Sensor Selection

- Two commercial-grade personal exposure sensors, **Flow 2 and Atmotube Pro**, were evaluated in chamber testing and via collocation with reference instruments summer 2021
- The Atmotube Pro was selected for personal exposure measurements based on:
  - Ease of use
  - App quality
  - Data availability
  - Sensor accuracy
  - Measures **PM1, PM2.5** mass concentrations via nephelometry (Sensirion SPS30)
  - Measures **total volatile organic compounds** (TVOCs) with a metal-oxide sensor (Sensirion SGPC3)
  - GPS location tracking
- We measure ambient air quality at 5 locations in the community using QuantAQs
  - Combines a nephelometer and optical particle counter to measure **PM1, PM2.5, and PM10** mass concentrations

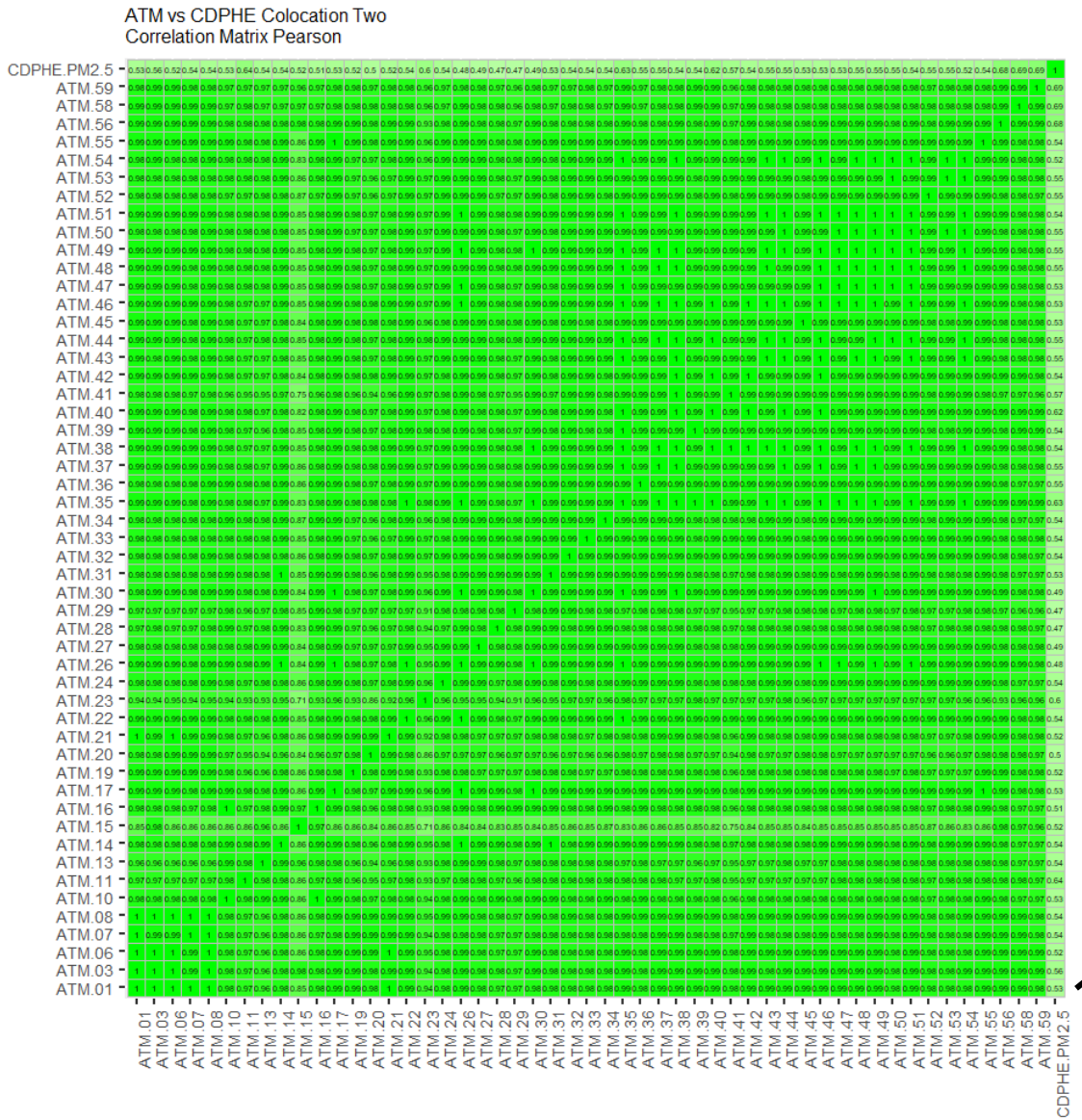
https://atmotube.com/atmotube-pro

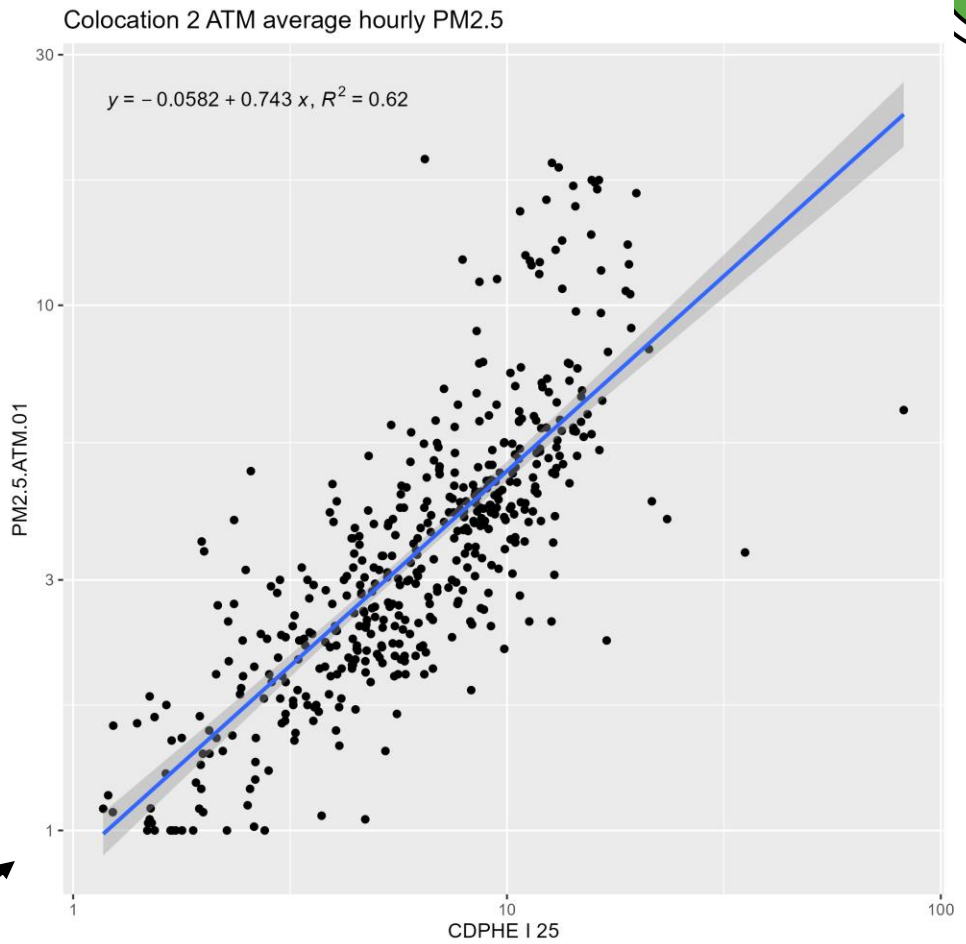
Air Sensor Colocation

- To determine accuracy of Atmotube and QuantAQ, sensors were installed at CDPHE/DDPHE sites with reference $PM_{2.5}$ instrumentation (GRIMM EDM180) for multiple weeks
- Data are used to create calibration equations for low-cost PM sensors
- **Summer 2021: Pilot colocation** CDPHE Globeville (6 days) and Swansea Elementary and I70 (DDPHE, 4 days)
- **Fall 2021**: Colocation at CDPHE Globeville for two weeks
- **Spring 2022:** Colocation at CDPHE Globeville for three to four weeks
- **Fall 2022:** Colocation at CDPHE Globeville for four weeks
- **Winter 2023:** Colocation at CDPHE Globeville for four weeks

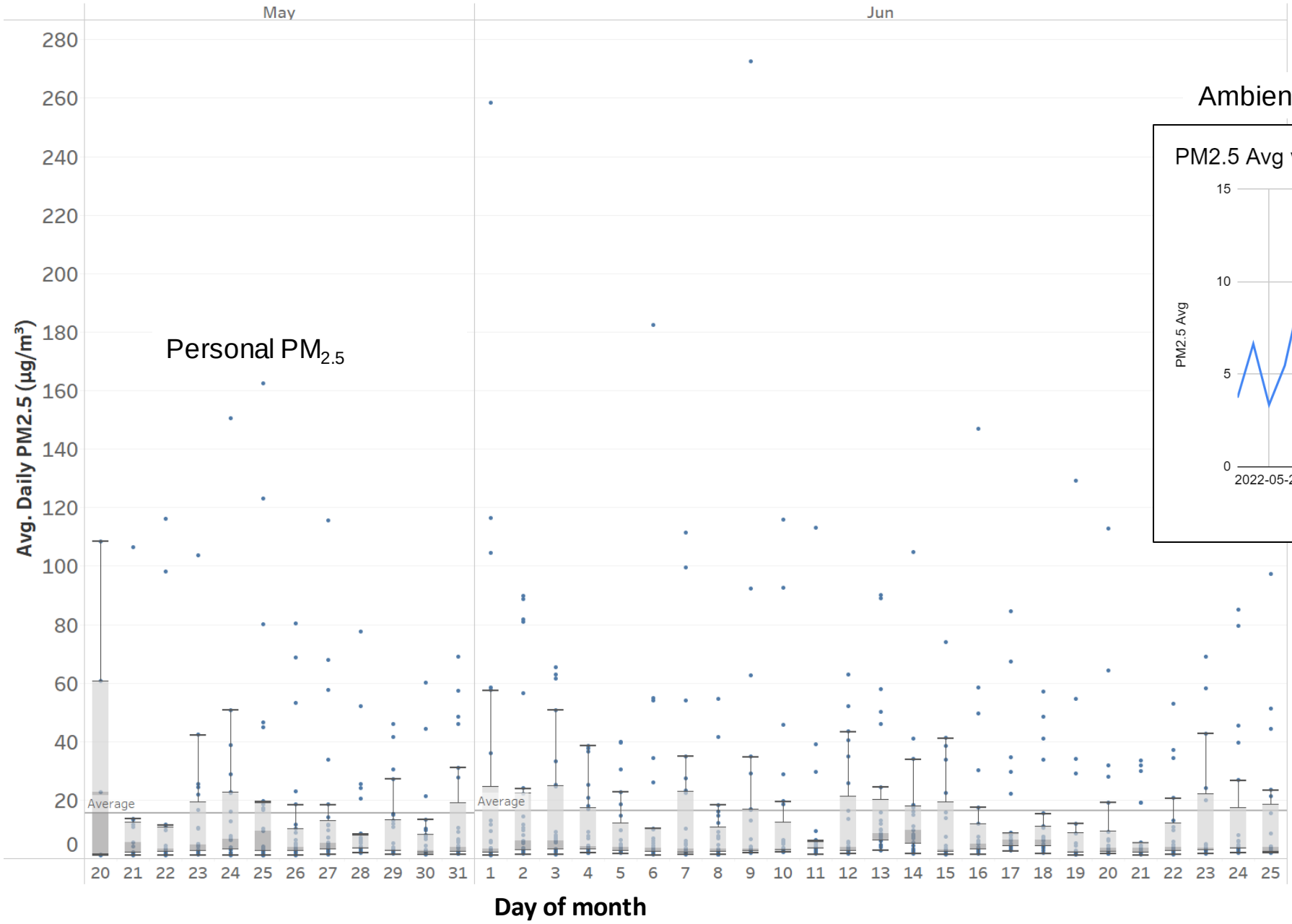


Air Sensor Colocation



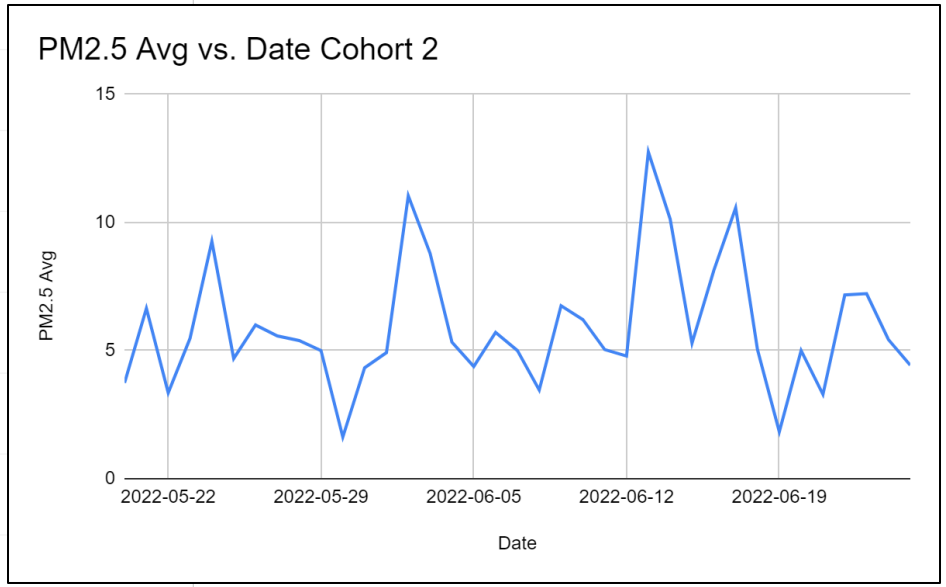


Daily average PM2.5 for participants in cohort two

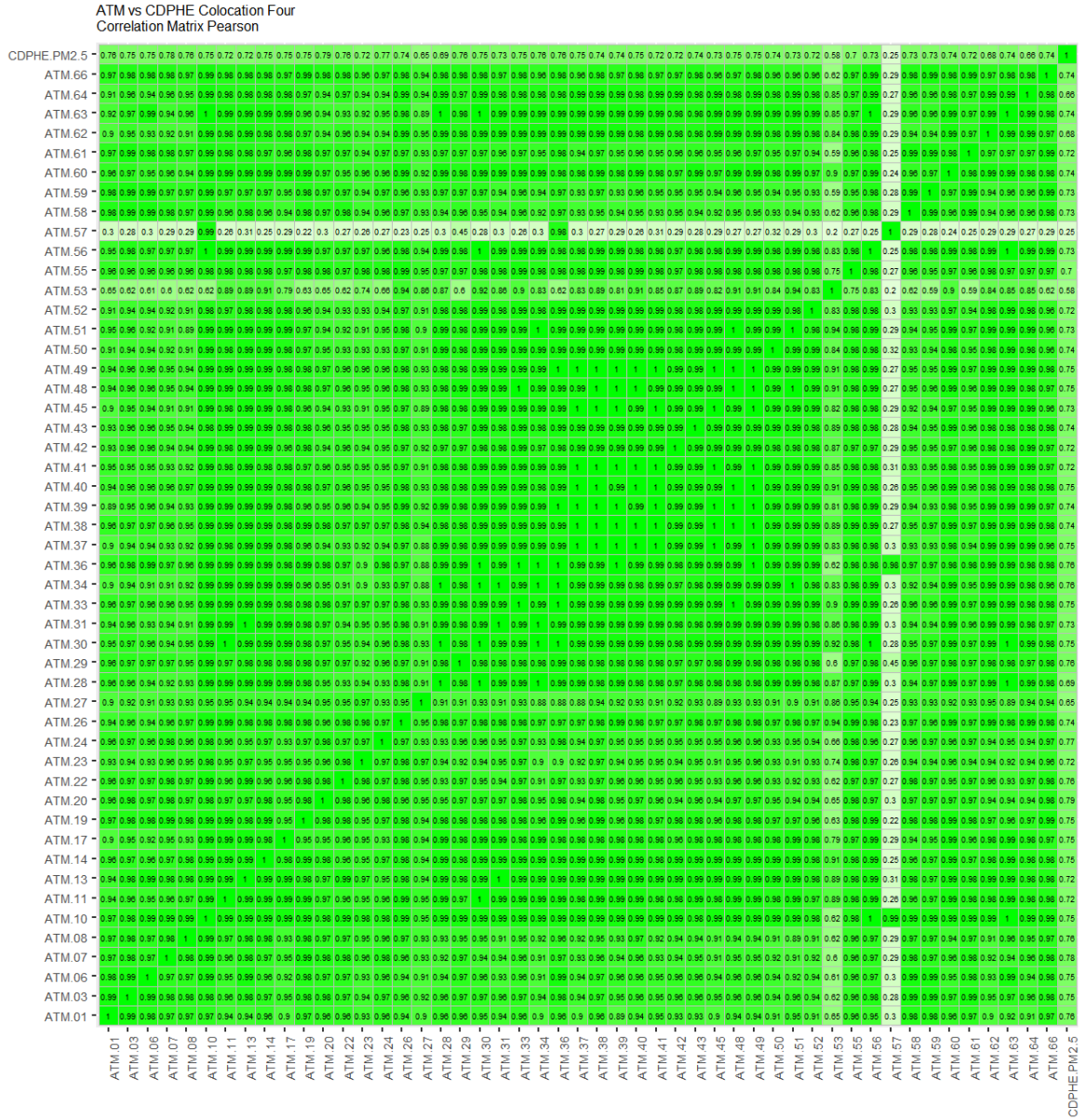


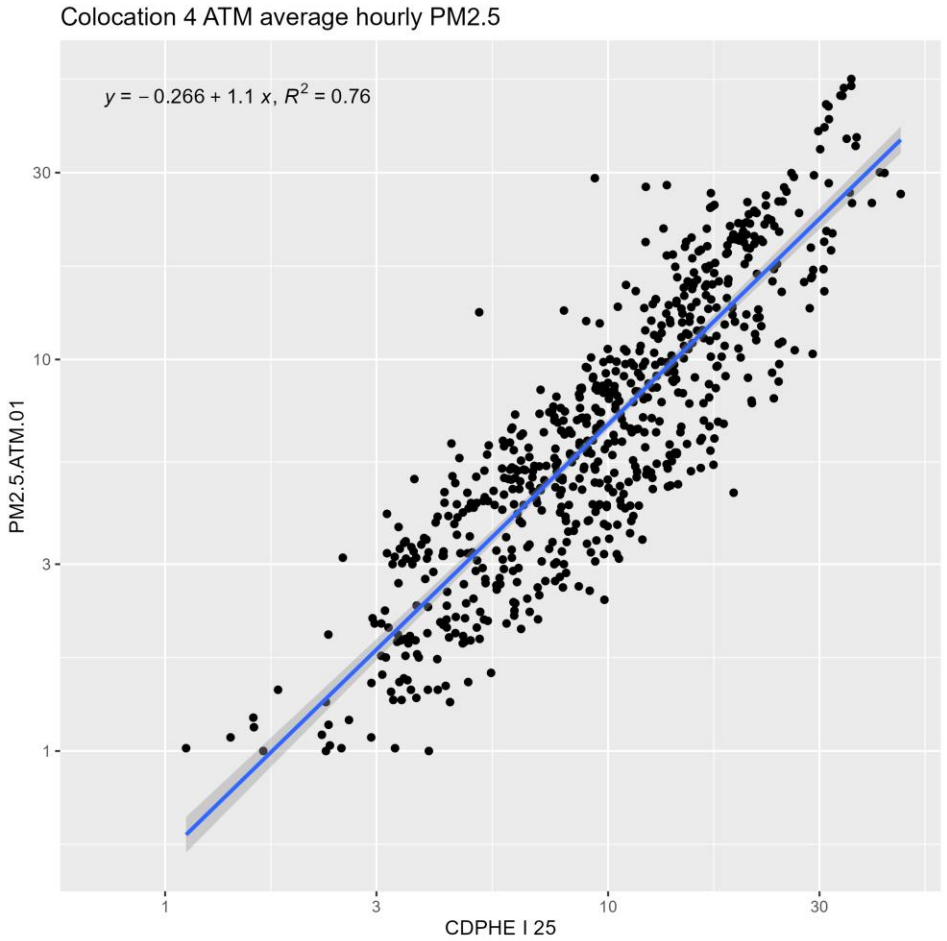
Personal $PM_{2.5}$

Ambient $PM_{2.5}$



Air Sensor Colocation





Personal Exposure

Your $PM_{2.5}$ Personal Exposure Data

ATM #50 User
These plots summarize your $PM_{2.5}$ personal exposure data measured by your atmotube. The data shown are from cohorts 3 and 4.

Figure 1 shows your average $PM_{2.5}$ personal exposure during cohort one (January 17th-March 4th 2022), cohort two (May 20th-June 25th 2022), cohort three (October 10th - November 10th), and cohort four (February 20th – March 20th 2023). The horizontal axis shows the month and the vertical axis shows your average $PM_{2.5}$ personal exposure during each month in units of microgram per cubic meter ($\mu g/m^3$). Cohort four included an intervention method provided by the SJEQ team. A Do-It-Yourself (D.I.Y.) Air Cleaner was used during the third and fourth cohorts to decrease the PM 2.5 levels in homes. The US EPA National Ambient Air Quality Standard for average annual $PM_{2.5}$ concentration is 12 $\mu g/m^3$.

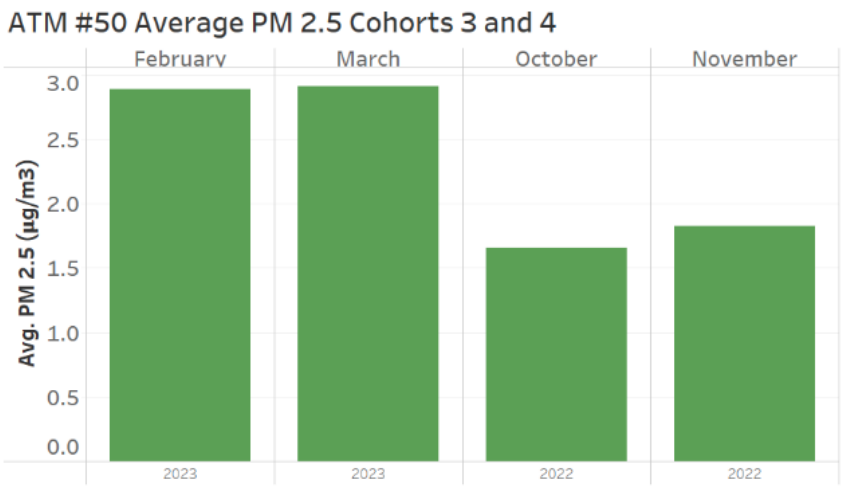


Figure 2 shows your overall PM2.5 exposure during cohort one (January 17th - March 4th, 2022), cohort two (May 20th - June 25th, 2022), cohort three (October 10th - November 10th, 2022), and cohort four (February 20th – March 20th 2023). Individual blue circles show your daily average PM2.5 personal exposure for the days in each month you synced your Atmotube.

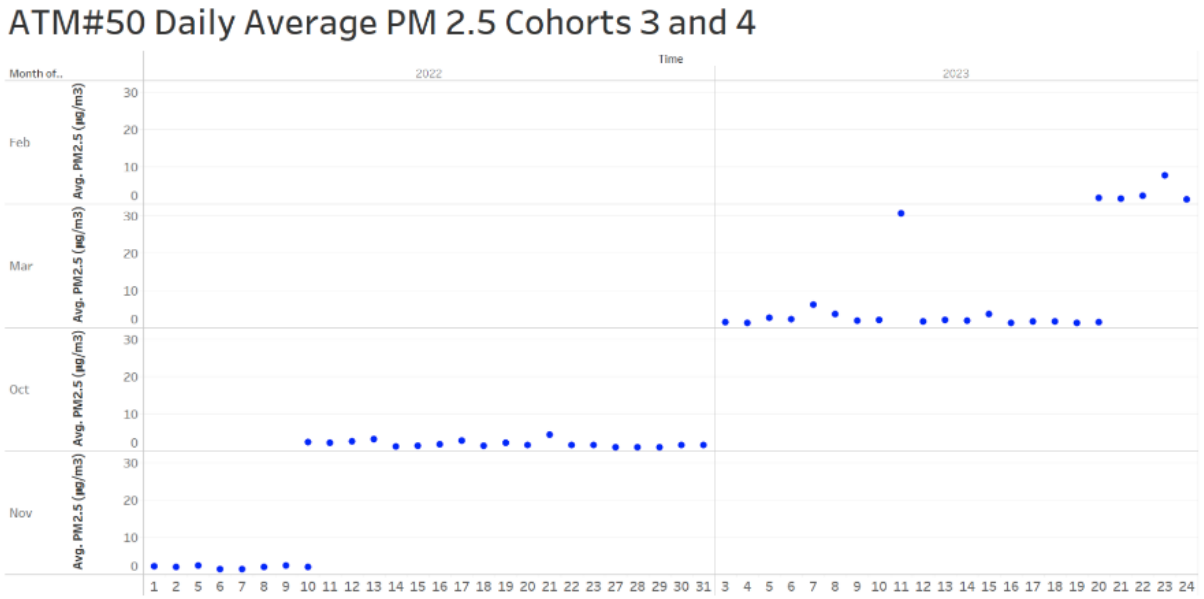


Figure 2.

Personal Exposure

Particulate Matter (PM)
Prepared by Environmental Engineering Team

What is PM?

- PM (often called as particle pollution) refers to a mixture of solid and liquid particles in air that can be inhaled and may cause serious health issues.
- PM is often categorized based on particle size into PM_{10} and $PM_{2.5}$ (Figure 1).
    - PM_{10} refers to particles that are less than 10 micrometers and smaller.
    - $PM_{2.5}$ particles are much smaller in size (less than 2.5 micrometers in diameter) and can penetrate deep within our respiratory system and are a greater health risk.

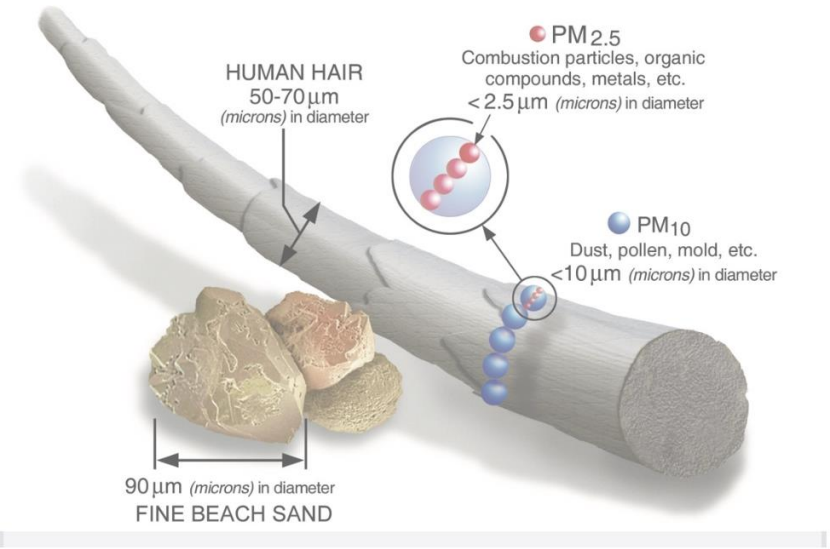
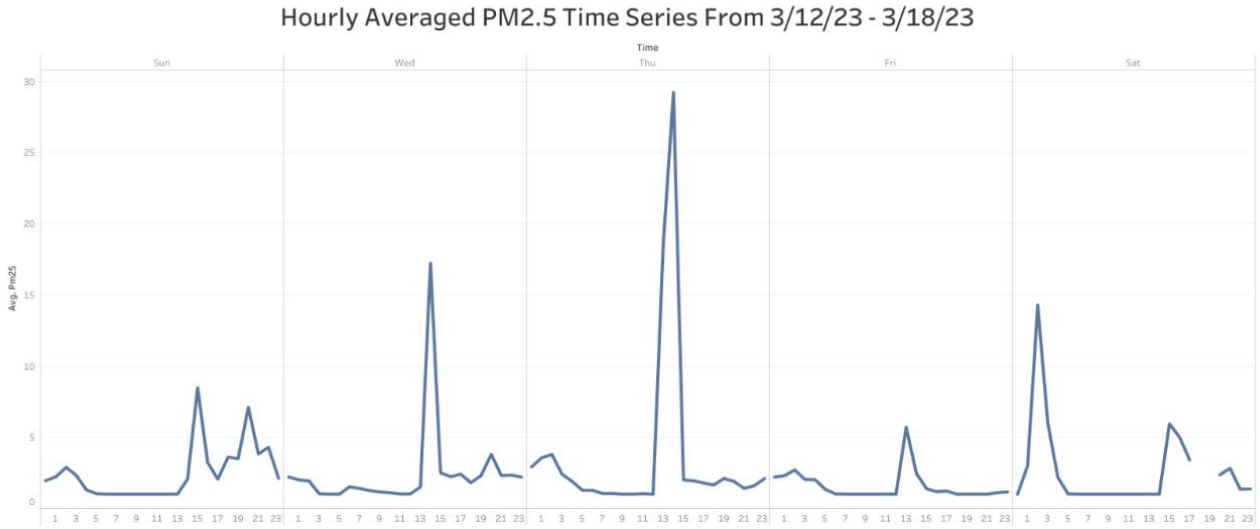
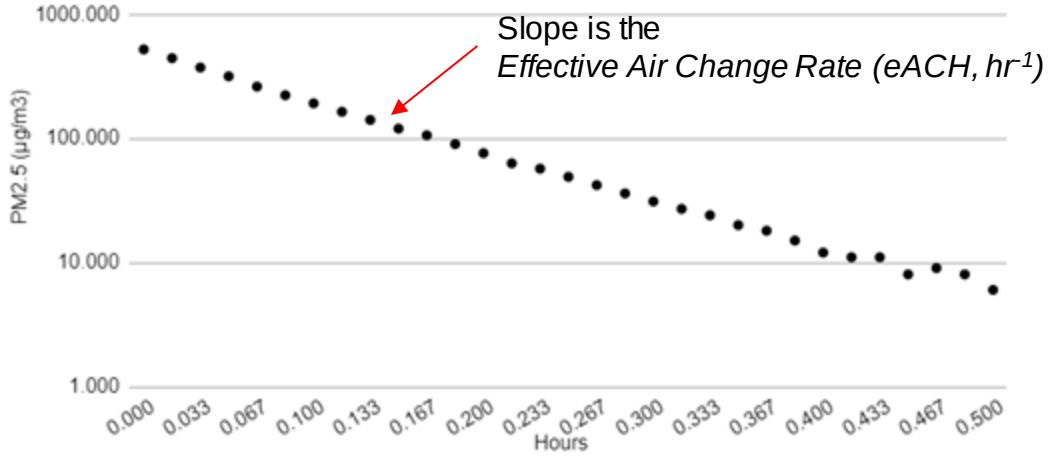


Figure 1. Size comparison for PM_{10} and $PM_{2.5}$ particles.

This plot shows you the hourly $PM_{2.5}$ average calculated for 24 hours of a day over a given week using the data provided by your Atmotube sensor. It shows you when during the day your exposure levels are higher.

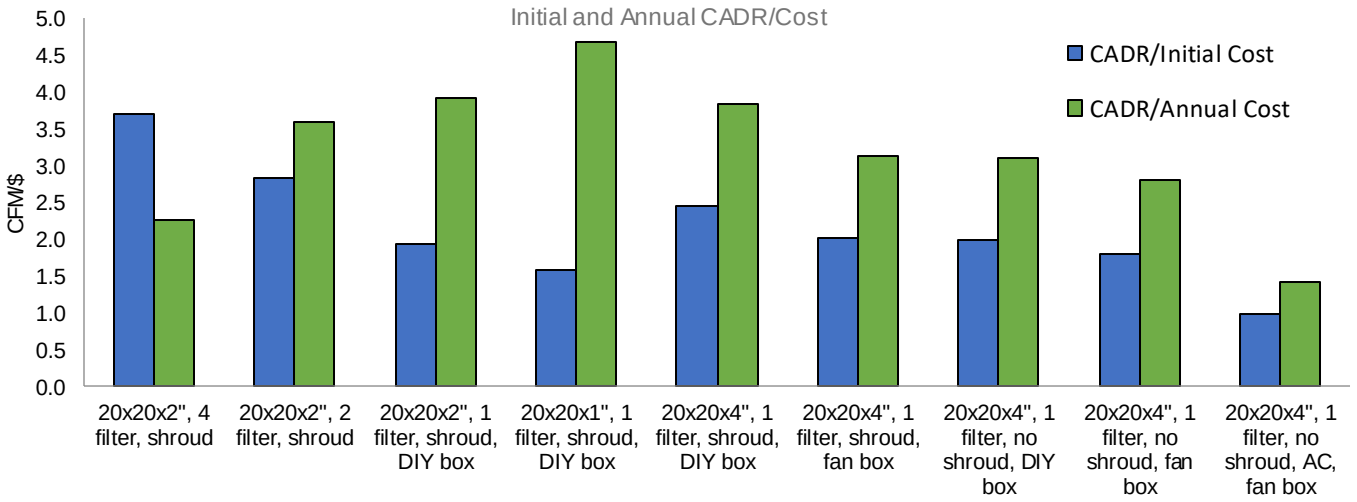


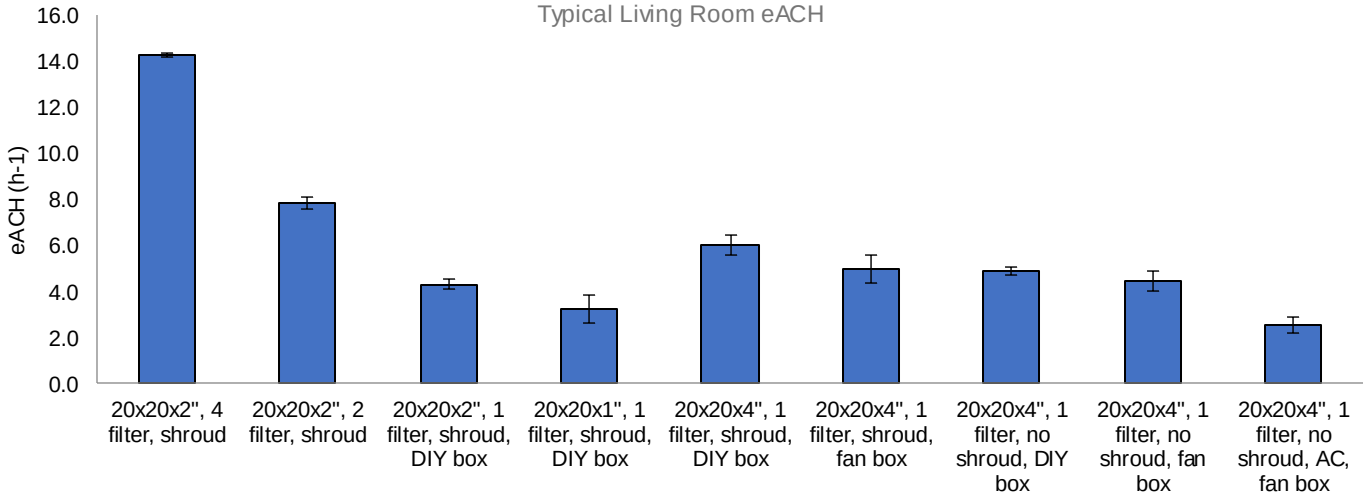
DIY Air Cleaner Intervention



	1-MERV13 Filter, 20x20x1" (shroud)	1-MERV13 Filter, 20x20x2" (shroud)	1-MERV13 Filter, 20x20x4" (shroud)	1-MERV13 Filter, 20x20x4" (no shroud)	2-MERV13 Filters, 20x20x2" (shroud)	4-MERV13 Filters, 20x20x2" (shroud)
CADR ($PM_{2.5}$) [ft^3/min]	108 😩	127 😟	127 😟	149 🙂	230 😁	415 😁
Ease of Build	Medium 🙂	Medium 🙂	Medium 🙂	Easiest 😁	Hardest 😩	Hard 😟
Size	Small 😁	Small 😁	Small 😁	Small 😁	Medium 🙂	Large 😩
Initial (Annual) Cost ($)	$59 ($20) 😁	$65 ($32) 😁	$72 ($46) 🙂	$72 ($46) 🙂	$81 ($64) 😟	$113 ($184) 😩
CADR/Initial Cost [ft^3/min-$]	1.8 😟	2.0 🙂	1.8 😟	2.1 🙂	2.8 😁	3.7 😁
CADR/Annual Cost [ft^3/min-$]	5.4 😁	4.0 😁	2.8 😟	3.2 🙂	3.6 😁	2.3 😩

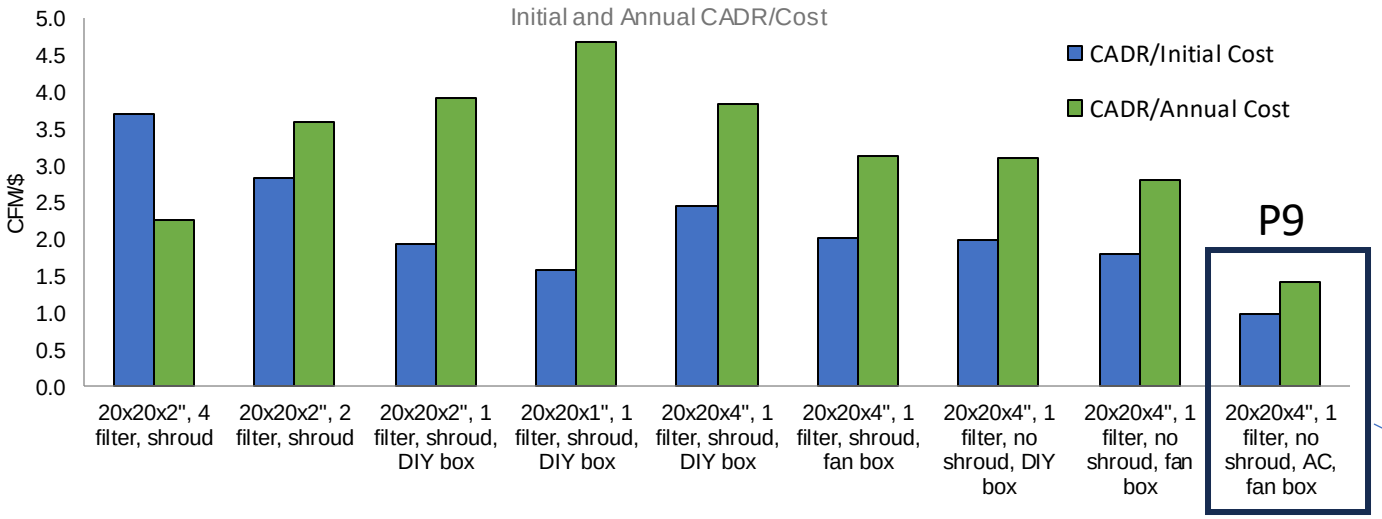
Optimization of a DIY Air Cleaner Design to Reduce Residential Air Pollution Exposure for a Community Experiencing Environmental Injustices

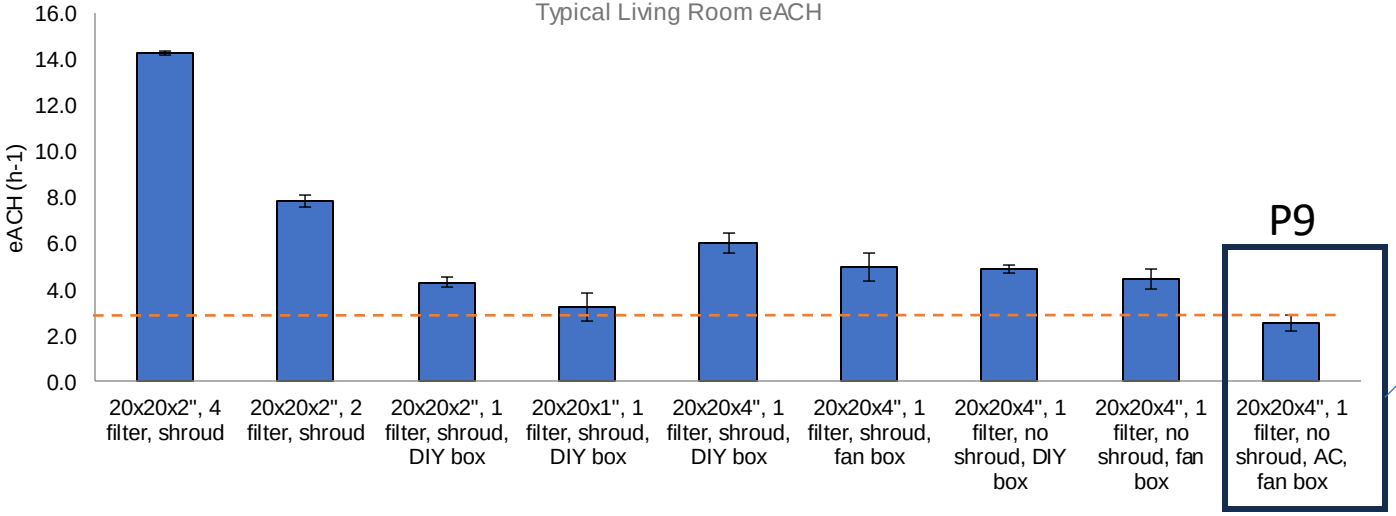




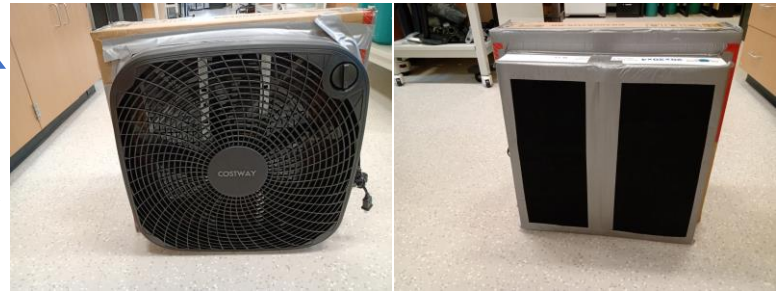
- In general, single filter prototypes had higher CADR/Annual Cost values than multiple filter configurations.
- The presence of shroud does lead to CADR increase but also leads to the complexity of the build.
- Including activated carbon layer over HEPA filter also led to lower removal rate values.

Optimization of a DIY Air Cleaner Design to Reduce Residential Air Pollution Exposure for a Community Experiencing Environmental Injustices

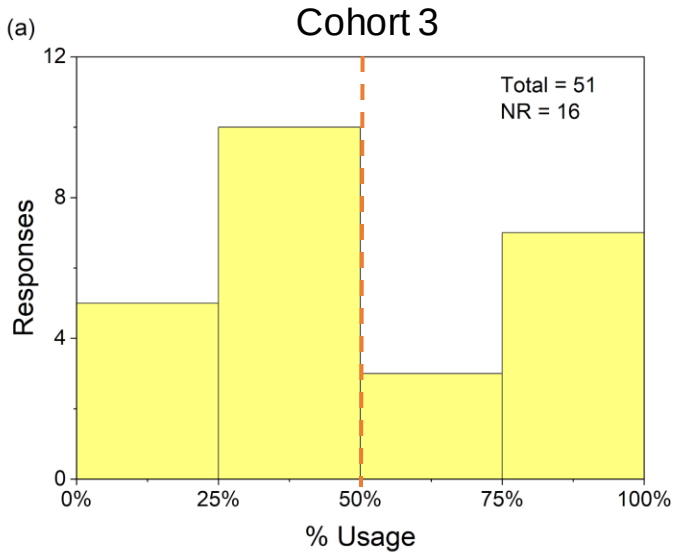


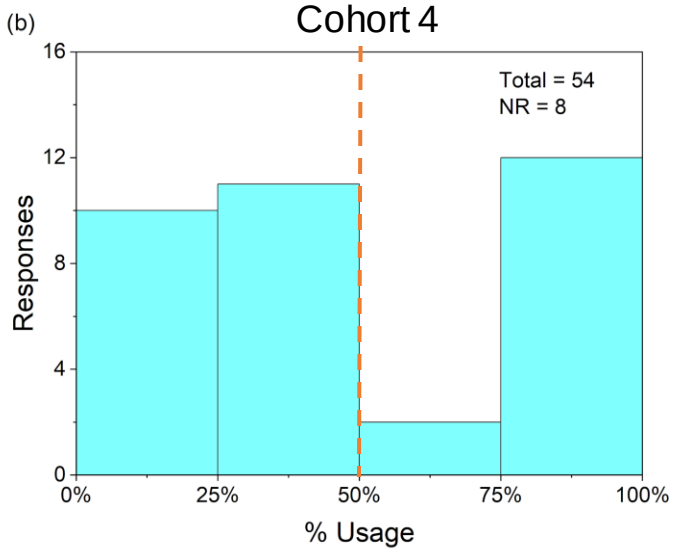


P9 was selected based on combination of factors such as ease of build, floor area occupied, and to include the additional VOC removal rate of ~0.5 hr^{-1} associated with it.



Still a lot of awareness is needed to promote their consistent use





"I did use the air cleaner fan this past week almost everyday during the day time. But only on the days that the temperature was warmer. Too cold to run it on cold days & during sleep."

"just whenever I decide to turn it on , mostly at night. It's very big & takes up space. If it was smaller & fit the aesthetic of our space (lol) I would use it "

"seemed to hold atm measurements to good air except when cooking"

"all the time, we use it I. Our basement since the airflow isn't as good as our main floor"

SJEQ-D Social Science Team: Methods and Findings

Community Engagement and Recruitment

- **4 Community Connectors** hired through Groundwork Denver.
- Building relationships with community organizations since January 2021.
- Attendance at Community and Nonprofit events/meetings.
- Engaged GESCC residents and community organizations through frequent social media posts on Instagram and Facebook.
- Community canvassing through all 5 neighborhoods for each cohort recruitment.
- **Recruited** approximately **548 residents** and **onboarded** around **440 people** in the study.

Focus Groups and Findings

Participants: 32 Residents of Globeville, Elyria-Swansea, and Cole neighborhoods

Construction Issues

- Major concerns related to traffic and road closures
- Increased time spent commuting and unanticipated delays
- Constant noise and increased dust

Health Impacts of Construction

- Increased experiences of frustration, annoyance, more daily stress, depression, anxiety
- Concerned about personal and family health and wellbeing
- Reported worsening asthma, respiratory issues, allergies, dry throat, cough, headaches

Community Belonging

- Don’t feel listened to by the city/government agencies, feeling overlooked
- Neighborhood doesn’t feel the same anymore since construction started

Long Survey – Demographics

	Cohort 1	Cohort 2	Cohort 3	Cohort 4
Relationship to household head				
Self	66.30%	69.31%	58.46%	73.40%
Dependent	4.35%	6.93%	9.23%	2.13%
Partner	29.35%	23.76%	32.31%	24.47%
Number of people at home (Including the respondent)	3.05 (1.68)	2.87 (1.60)	2.83 (1.44)	3.03 (1.83)
Respondent's gender				
Man	21.74%	20.79%	23.08%	32.98%
Women	75.00%	76.24%	72.31%	63.83%
Other	3.26%	2.97%	4.62%	3.19%
Age	40.81 (12.28)	41.30 (12.22)	40.33 (11.16)	41.96 (12.32)
Marital status				
Married	41.30%	42.16%	42.42%	45.74%
Employment status				
Full-time	59.78%	52.48%	56.06%	55.32%
Highest education degree				
Less than high school	8.70%	8.82%	10.61%	8.51%
High school diploma or GED	11.96%	11.76%	12.12%	11.70%
Some college, no degree	20.65%	20.59%	22.73%	21.28%
Associate's degree	6.52%	5.88%	4.55%	4.26%
Bachelor's degree	32.61%	31.37%	27.27%	30.85%
Graduate degree or professional degree	19.57%	21.57%	22.73%	23.40%

Long Survey - Demographics

	Cohort 1	Cohort 2	Cohort 3	Cohort 4
Respondent's race-ethnicity				
Non-White %	51.09%	55.79%	50.00%	53.85%
Non- Black %	3.26%	3.16%	1.52%	3.30%
Non-Hispanic %	36.96%	31.58%	37.88%	32.97%
Indigenous American or Alaskan Native	3.26%	2.11%	4.55%	1.10%
Asian and/or Pacific Islander	2.17%	2.11%	1.52%	2.20%
Other	3.26%	5.26%	4.55%	6.59%
Combined household income				
0-$9,999	5.49%	4.90%	7.58%	5.43%
$10,000-24,999	14.29%	9.80%	12.12%	11.96%
$25,000-49,000	18.68%	21.57%	16.67%	20.65%
$50,000-74,999	18.68%	22.55%	22.73%	14.13%
$75,000-99,999	14.29%	10.78%	15.15%	13.04%
$100,000-124,000	8.79%	13.73%	9.09%	7.61%
More than $125,000	19.78%	16.67%	16.67%	27.17%
Year of home built				
I don't know	24.44%	35.37%	23.08%	18.09%
1919 or before	27.78%	14.63%	24.62%	22.34%
1920s-1930s	15.56%	20.73%	12.31%	14.89%
1940s-1950s	13.33%	8.54%	16.92%	22.34%
1960s-1970s	2.22%	4.88%	6.15%	5.32%
1980s-1990s	3.33%	3.66%	3.08%	4.26%
2000 or after	13.33%	12.20%	13.85%	12.77%
Home type				
Single family home	78.89%	77.00%	70.77%	68.09%
Mobile home	2.22%	1.00%	1.54%	3.19%
Apartment	4.44%	7.00%	12.31%	8.51%
Townhome	8.89%	10.00%	7.69%	9.57%
Other	5.56%	5.00%	7.69%	10.64%
Own, rent, or occupy				
Owned or being bought	66.67%	66.00%	64.62%	60.64%
Rented	32.22%	30.00%	33.85%	39.36%

Atmotube Interviews

Participants: 30 of the 50 Atmotube users in Cohorts 1, 2 ,3 4. Totaling 120 interviews. 98 of these participants conducted at least two interviews with us.

Interview Design: Semistructured interview guide focuses on:

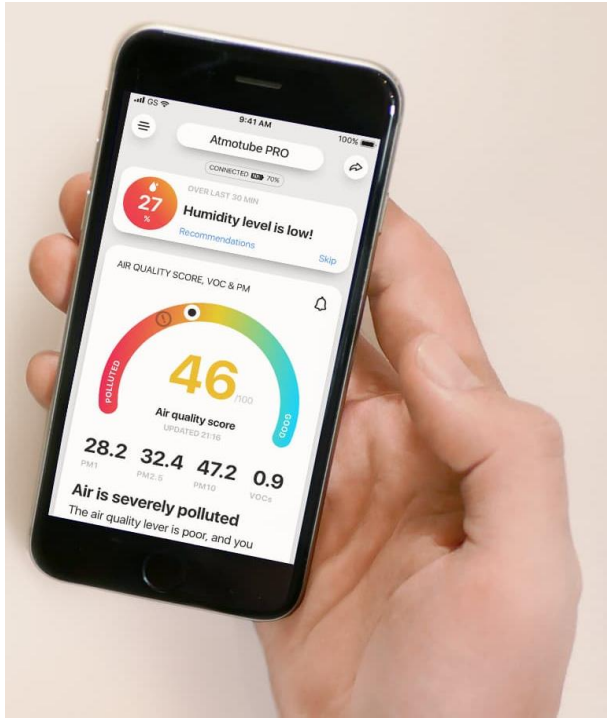
- Motivation to carry the sensor
- How they used/interpreted data
- What they expected to learn vs. what they actually learned
- Feelings regarding their personal environment before and after using the sensor
- Whether they changed their behaviors, environments, or routines after using the sensor
- Difficulties encountered using the sensor
- Feedback about participating in a community science project using a sensor

Air Quality Sensors Build Exposure Awareness:

- 71% of participants said the main benefit of carrying the sensor was building awareness about air pollution exposure in relation to health

- Participants **understand** sensor data via the Atmotube app regardless of pre-existing level of scientific literacy

- Participants **documented** concerns in their neighborhoods and especially in their own homes



Air Quality Sensors Foster Community Science:

Participants experimented with their sensor to:

1. **Validate** existing sensory experiences and concerns over known polluters in their area (ex. noxious odors from local smelters)
2. **Uncover** new, previously unknown sources of concern (ex. cooking or household chemicals)
3. **Investigate** health concerns
    - **Susan: “Over time, I kept showing my partner the air quality is better by 5-10 points or something, if we have a purifier on. We have it on a schedule now, right before we come home, and it stays on until bedtime."**

Air Quality Sensors Spark Behavioral Change:

- 50% of participants adopted mitigation behaviors after identifying poor air quality with the sensors

- 40% of participants adopted protective behaviors, such as going outside when outdoor air was better or frequenting locations in neighborhood with lower air pollution scores

Obstacles to Behavioral Change

- 37% Residents did not report any behavior changes
- Six residents expressed not knowing what to do to improve air quality
- Four residents reported that they wanted specific guidance on how to improve air quality that went beyond what the sensor provided.
- Knowledge of air quality gained using a personal sensor was valuable for the individual, but this potentially narrows the scope of residents' environmental action in the community

Report Back and Emerging Findings

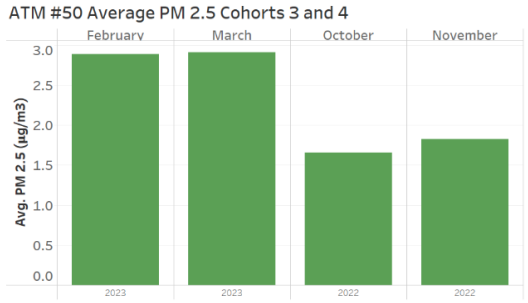
- Continued coding after Cohorts 1 and 2.
- After cohort 2, each participant received a summary of their PM 2.5 levels.
- In cohorts 3 and 4, social science team members went through these individual summaries with participants.
- Participants will have the opportunity to speak with Environmental Engineers directly.

Your $PM_{2.5}$ Personal Exposure Data

ATM #50 User

These plots summarize your $PM_{2.5}$ personal exposure data measured by your atmotube. The data shown are from cohorts 3 and 4.

Figure 1 shows your average $PM_{2.5}$ personal exposure during cohort one (January 17th-March 4th 2022), cohort two (May 20th-June 25th 2022), cohort three (October 10th - November 10th), and cohort four (February 20th – March 20th 2023). The horizontal axis shows the month and the vertical axis shows your average $PM_{2.5}$ personal exposure during each month in units of microgram per cubic meter ($\mu g/m^3$). Cohort four included an intervention method provided by the SJEQ team. A Do-It-Yourself (D.I.Y.) Air Cleaner was used during the third and fourth cohorts to decrease the PM 2.5 levels in homes. The US EPA National Ambient Air Quality Standard for average annual $PM_{2.5}$ concentration is 12 $\mu g/m^3$.



Particulate Matter (PM)

Prepared by Environmental Engineering Team

What is PM?

- PM (often called as particle pollution) refers to a mixture of solid and liquid particles in air that can be inhaled and may cause serious health issues.
- PM is often categorized based on particle size into PM_{10} and $PM_{2.5}$ (Figure 1).
  - PM_{10} refers to particles that are less than 10 micrometers and smaller.
  - $PM_{2.5}$ particles are much smaller in size (less than 2.5 micrometers in diameter) and can penetrate deep within our respiratory system and are a greater health risk.

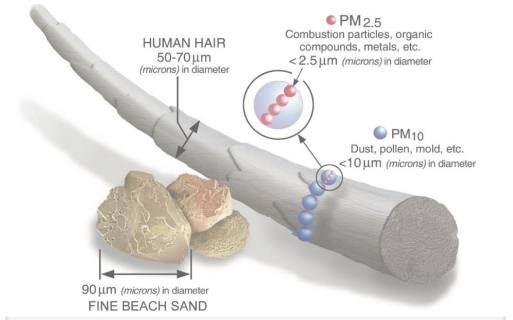
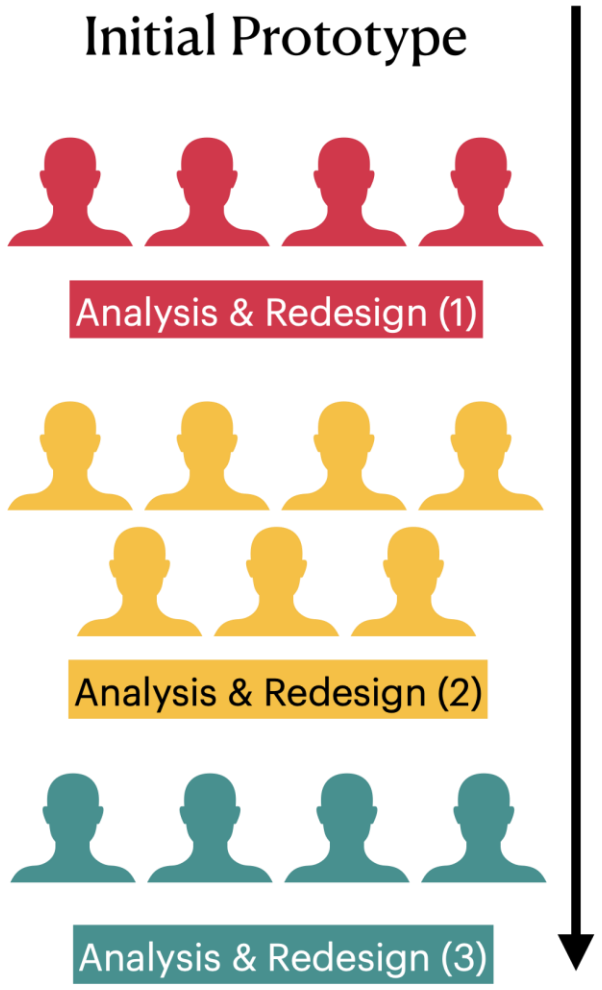


Figure 1. Size comparison for PM_{10} and $PM_{2.5}$ particles.

SJEQ-D Tech Team: Methods and Findings

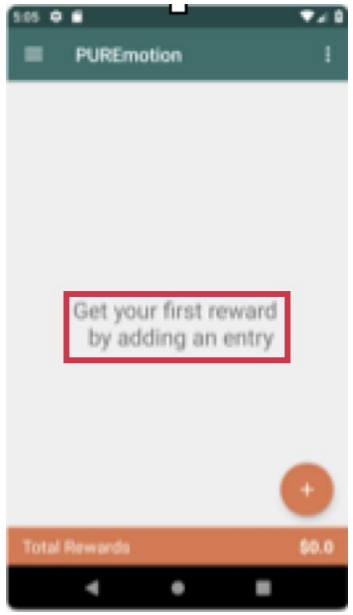
Usability study

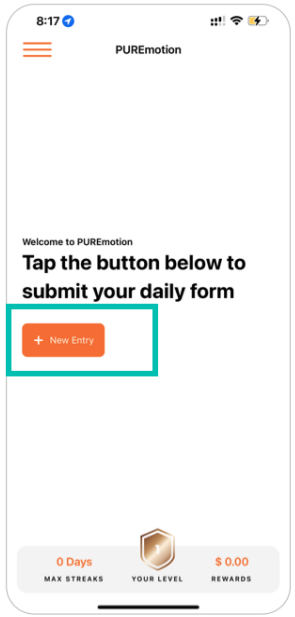
- 10-20 users will reveal 90 to 95 percent of the usability issues [37]
- 15 participants over 3 rounds
- Remote usability testing /User testing
- Perform tasks while thinking aloud [26, 34, 35]
- Spanish translator

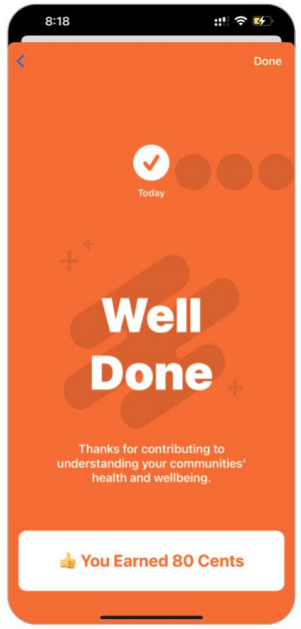


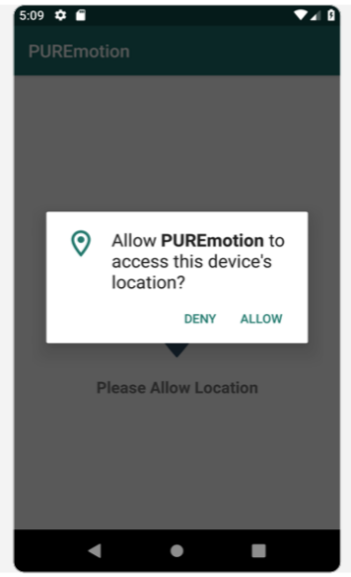
Usability issues

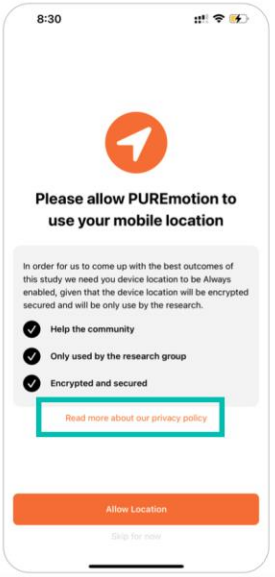
- Unclear how to start using the app
- Location sharing concerns
- Motivated by why



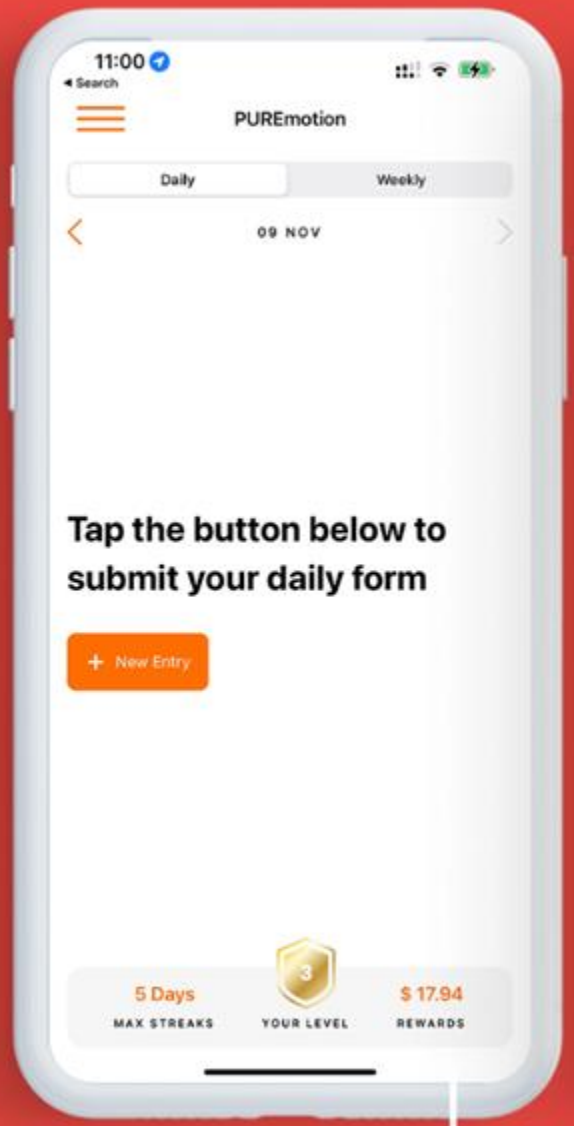




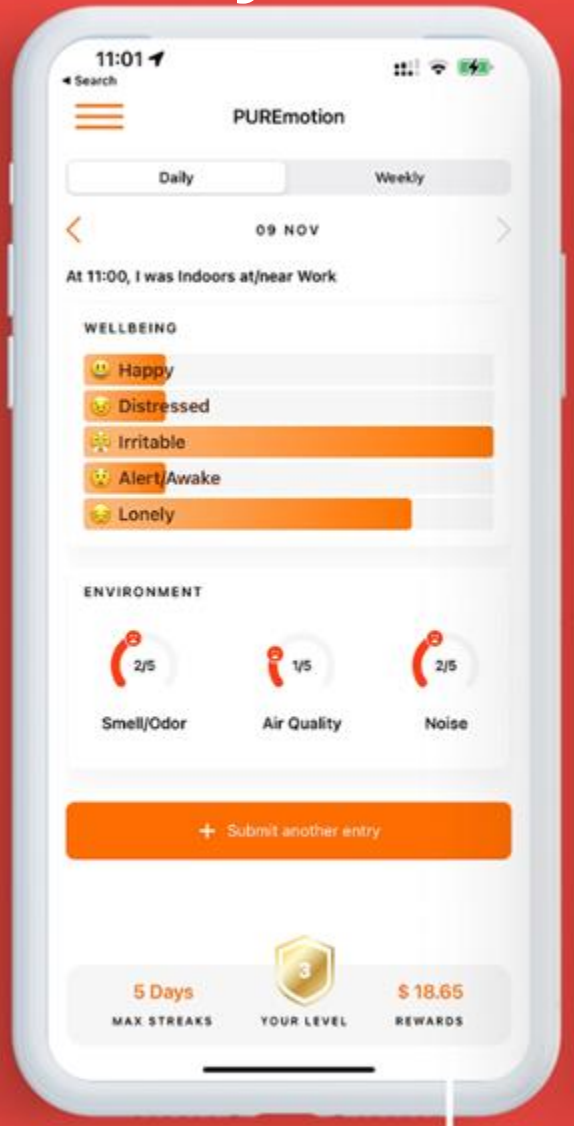




Puremotion Surveys

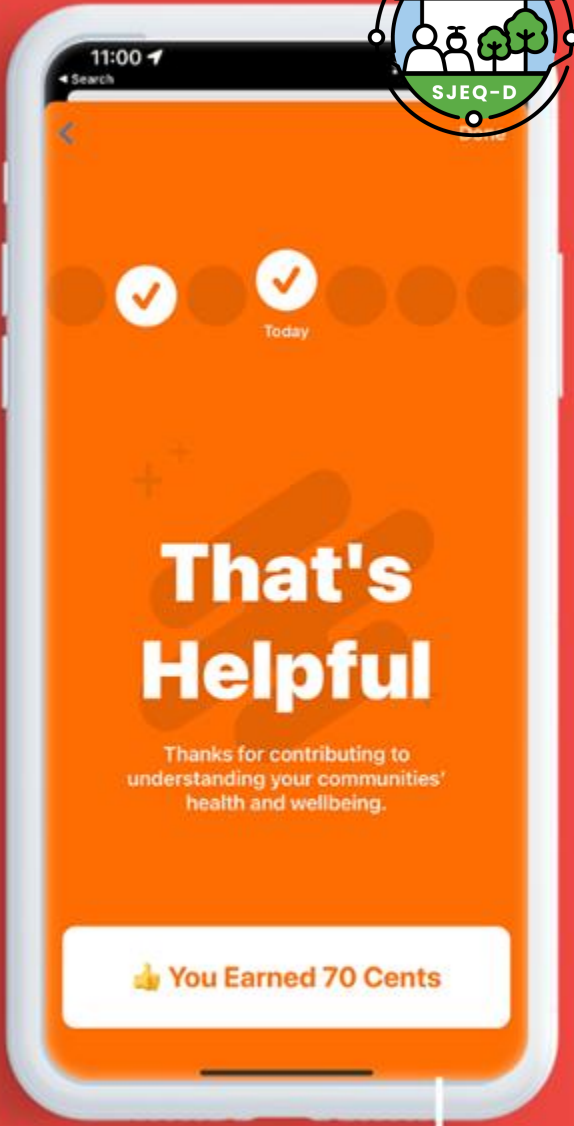


Data Collection



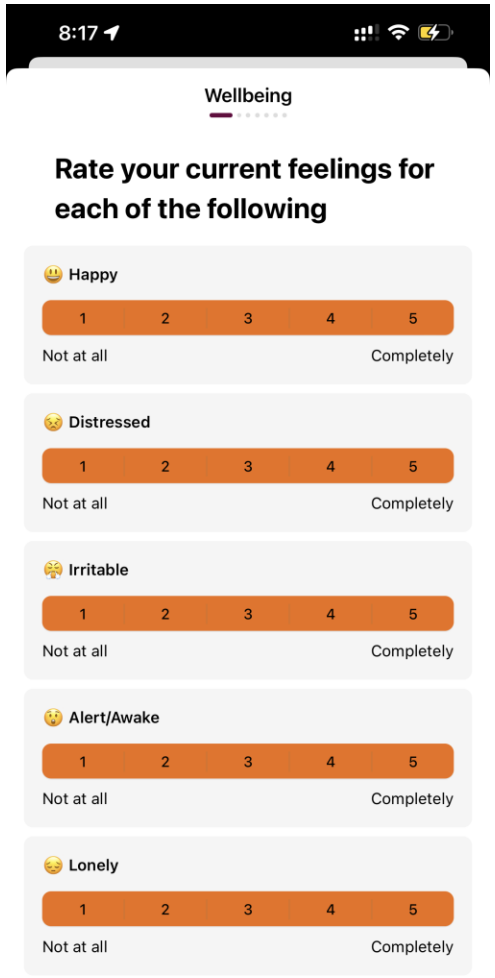
Daily Data

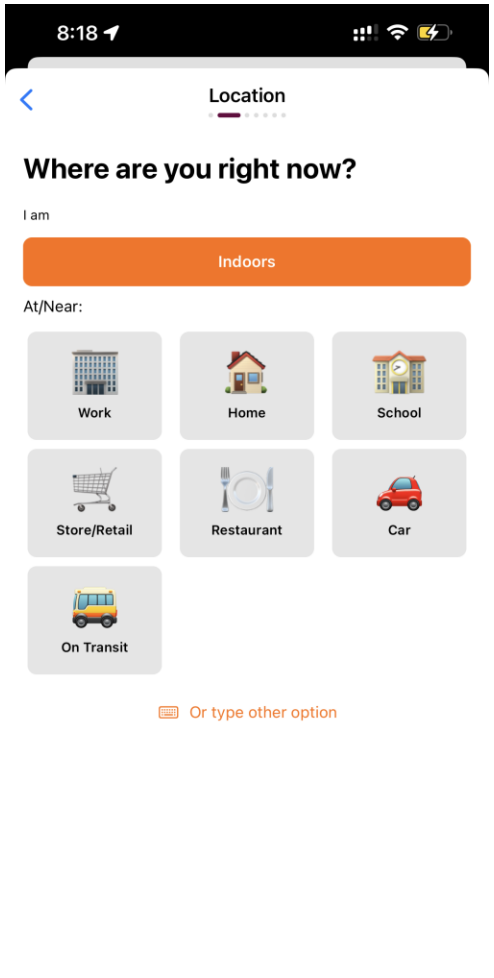
Weekly Data

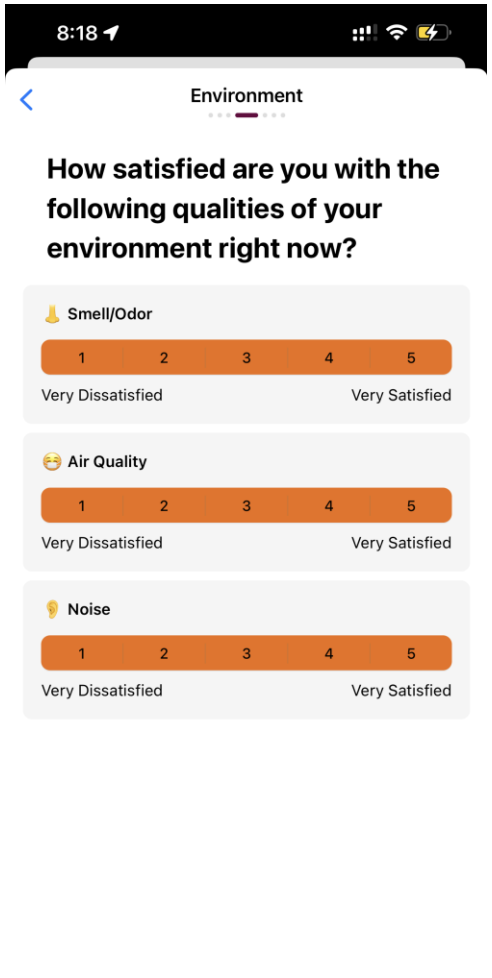


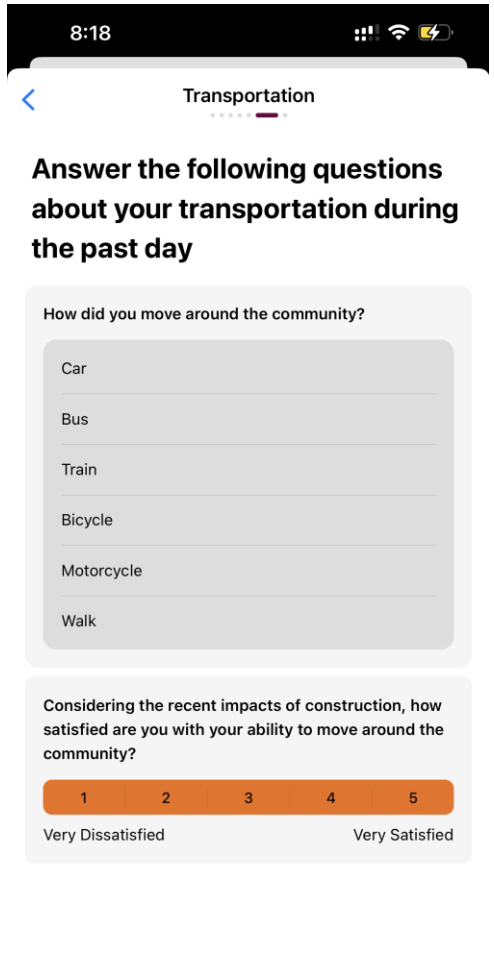
Data Streaks

Puremotion Surveys









Puremotion Surveys

cohort Place	1(%)	2(%)
Home Indoors	71.66	65.79
Work Indoors	8.23	10.06
Home Outdoors	3.24	9.33
Work Outdoors	1.39	2.23
Car Indoors	1.90	1.29
Walk/Bike Outdoors	1.39	1.46
Busy Road/Traffic Outdoors	1.54	1.29
Walk/bike Outdoors	0.51	1.33
Restaurant Indoors	1.39	0.60
Store/Retail Indoors	1.03	0.64

Table 4: Places of entries submission

Hours spent Outside	Cohort 1(%)	Cohort 2(%)
0-1 hours	63.94	40.27
2-3 hours	26.24	39.08
4-6 hours	5.73	13.13
More than 6 hours	4.09	7.52

Table 5: Number of hours spent outside

Note: Scale transformed to -1 to 1

Cohort	Happy	Distressed	Irritable	Alert/Awake	Lonely
1	0.627	-0.681	-0.732	0.398	-0.666
2	0.627	-0.633	-0.679	0.335	-0.723

Table 3: Average feelings levels

Satisfaction (/5) cohort	Air Quality	Noise	Smell/Order
1	0.301	0.337	0.336
2	0.161	0.135	0.242

Table 6: Satisfaction with environmental qualities

cohort	1		2	
	count	(%)	count	2 (%)
Smell/Odor	558	27.31	760	19.41
Dustiness	401	19.63	803	20.51
Allergies	330	16.15	836	21.35
Temperature	309	15.12	554	14.15
Mustiness	209	10.23	350	8.94
Smokiness	135	6.61	319	8.15
Visibility	101	4.94	294	7.51
Total Reports	2043		3916	

Table 7: Air Quality Complaints

Distance From construction & happiness

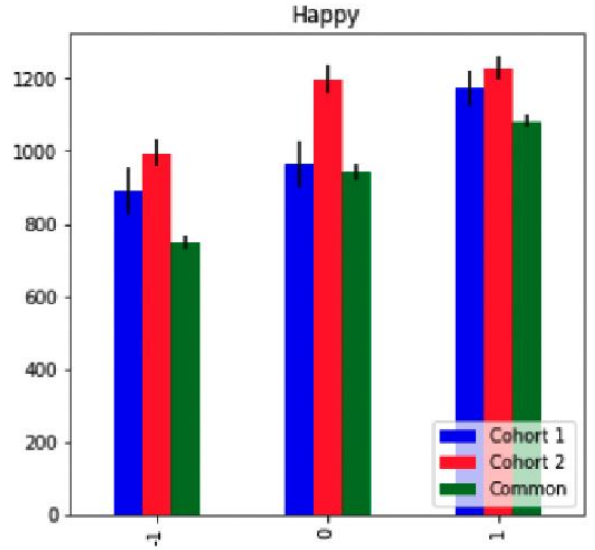


Fig. 10. Average distance from the nearest construction to the entry GPS location for Happy

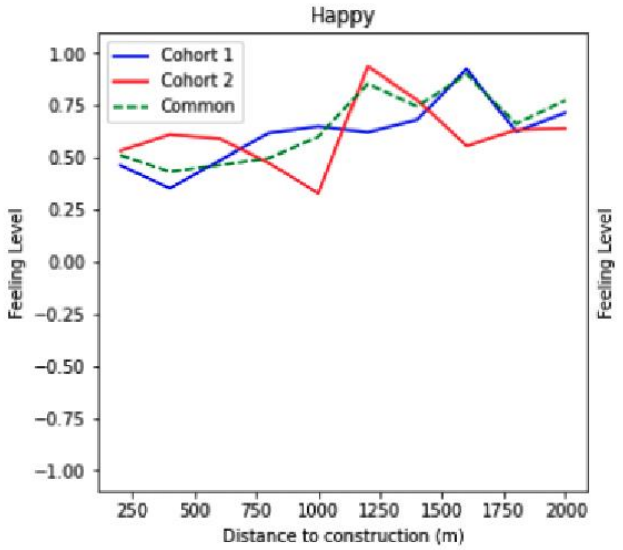
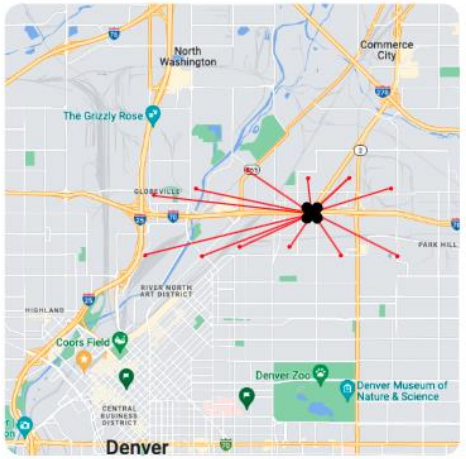
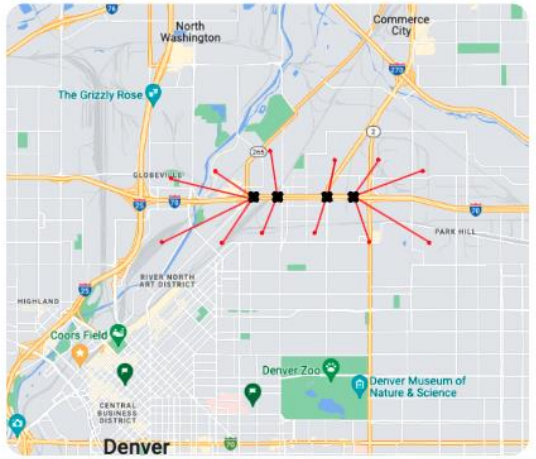


Fig. 11. Average feelings from each 200m distance from the nearest construction point to the entry GPS location



Method 1 (Center): Distance from point to center of construction

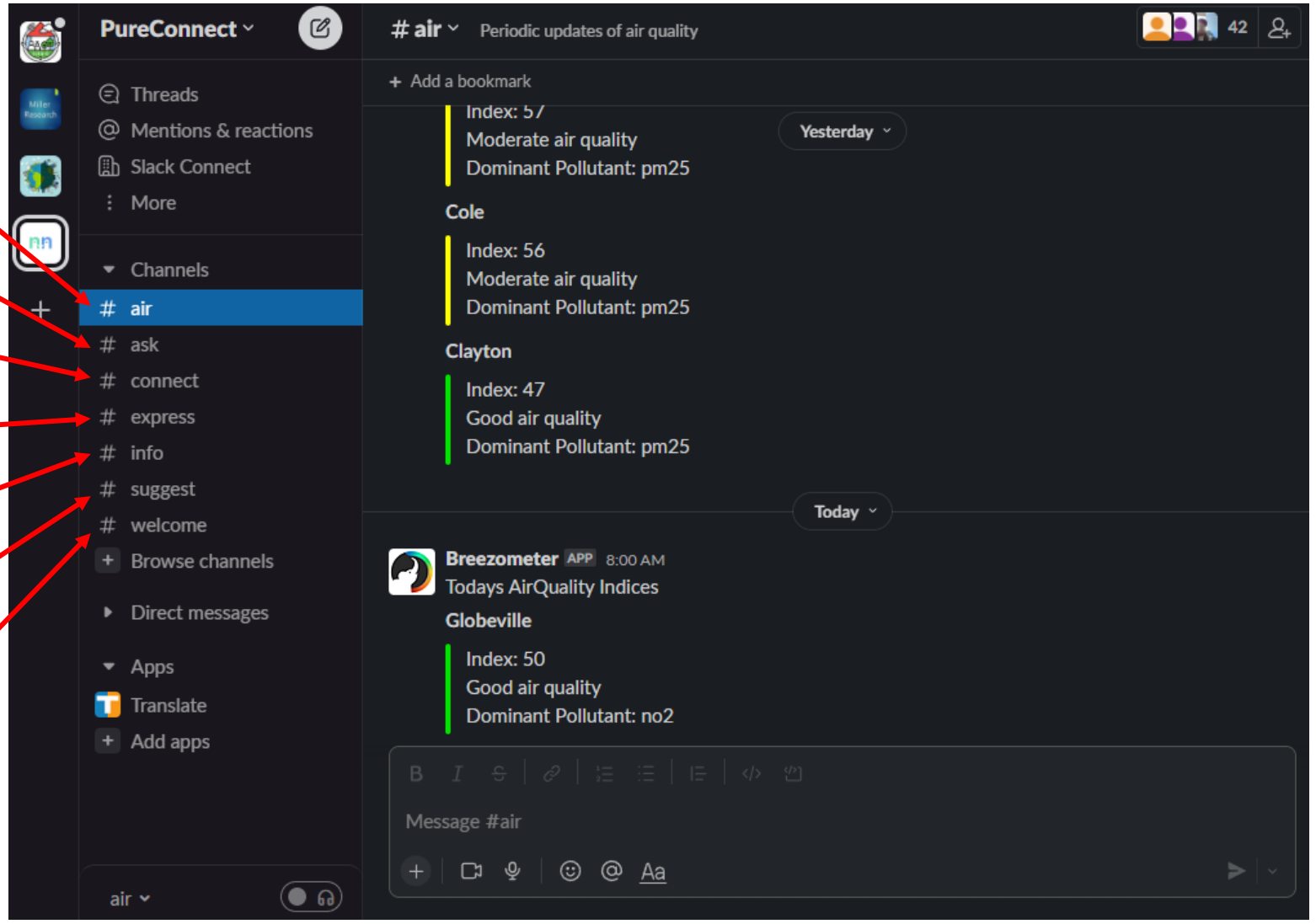
Method 2 (Highway): Vertical distance from point to highway



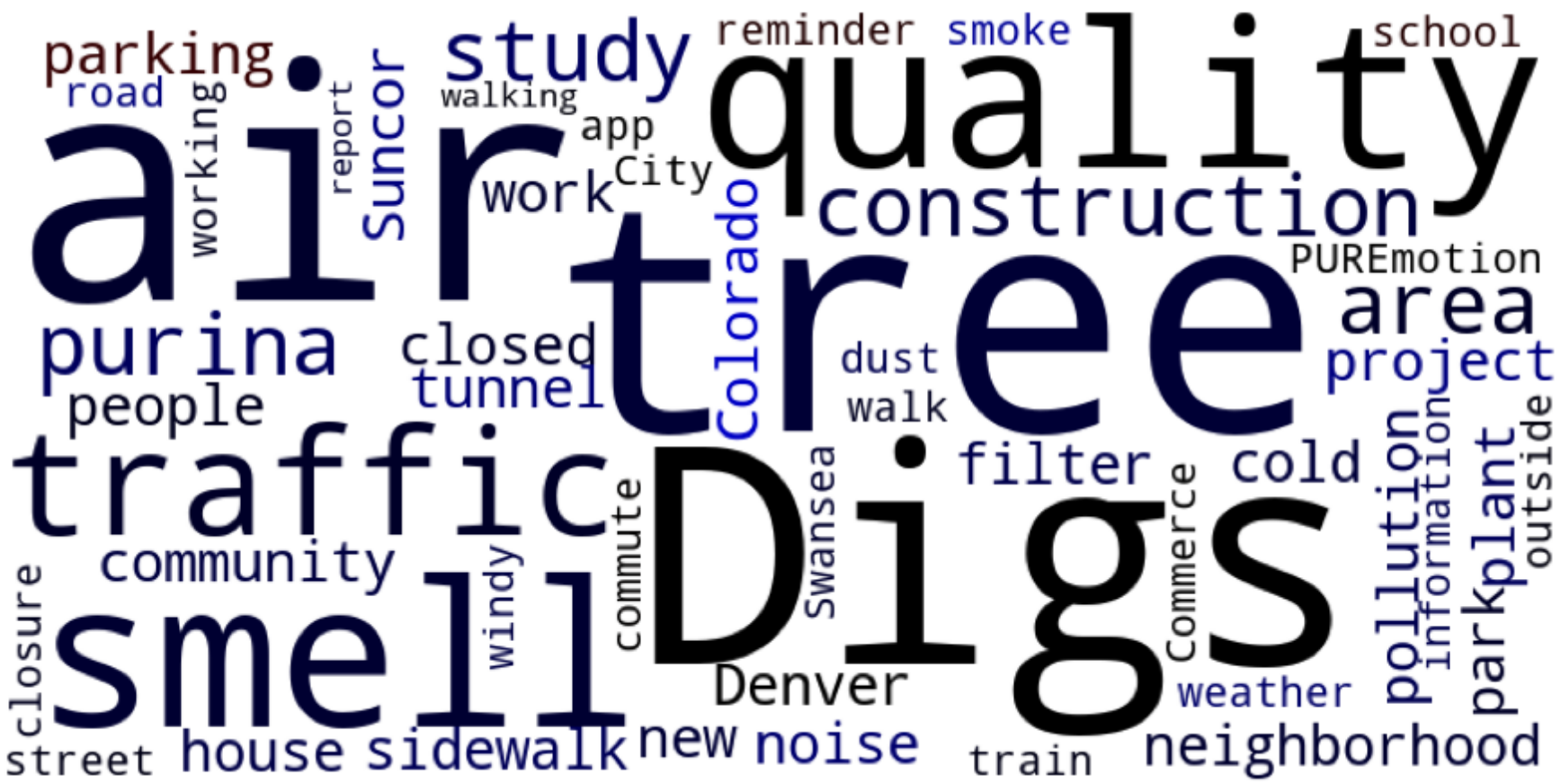
Method 3 (Nearest Point): distance from point to nearest construction activity at the time of reporting

PureConnect

- Daily neighborhood air pollution data
- Ask research team questions and chatbot
- General discussion between participants
- Express concerns related to construction
- Daily road status information for region
- Suggestions for mitigating issues
- PureConnect introduction and channel information



Word cloud & sentiments for Purenav

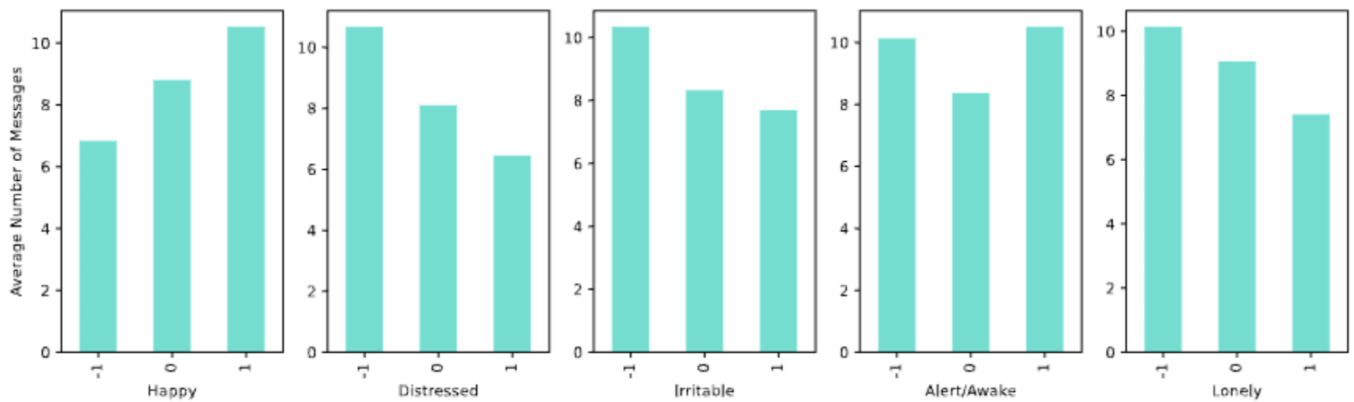


Example


Maria Alejandra Garcia Arambula 9:34 AM
Hoy es un día muy agradable cero olor a purina creo q el olor es más notable cuando es un día caluroso
Translate APP 9:34 AM
Today is a very nice day zero purina smell I think the smell is more noticeable when it's a hot day
Translated by @translate
1
Milliesouth 1:16 PM
Air quality is horrible with the high winds. So dusty/dirty and almost blew me off my feet so I'm not going anywhere else. purina stinks bad today as well
Translate APP 1:16 PM
La calidad del aire es horrible con los fuertes vientos. Tan polvoriento / sucio y casi me voló, así que no voy a ir a ningún otro lado. purina huele mal hoy también
Translated by @translate

Correlation of #messages & wellbeing

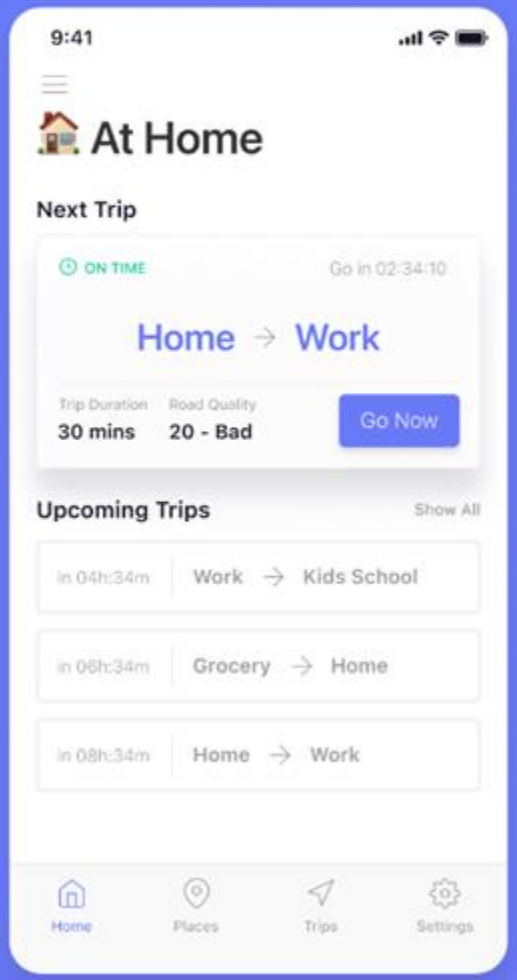
Feeling	Correlation with #Interactions
Happy	0.199
Distressed	-0.233
Irritable	-0.223
Alert/Awake	0.140
Lonely	-0.200



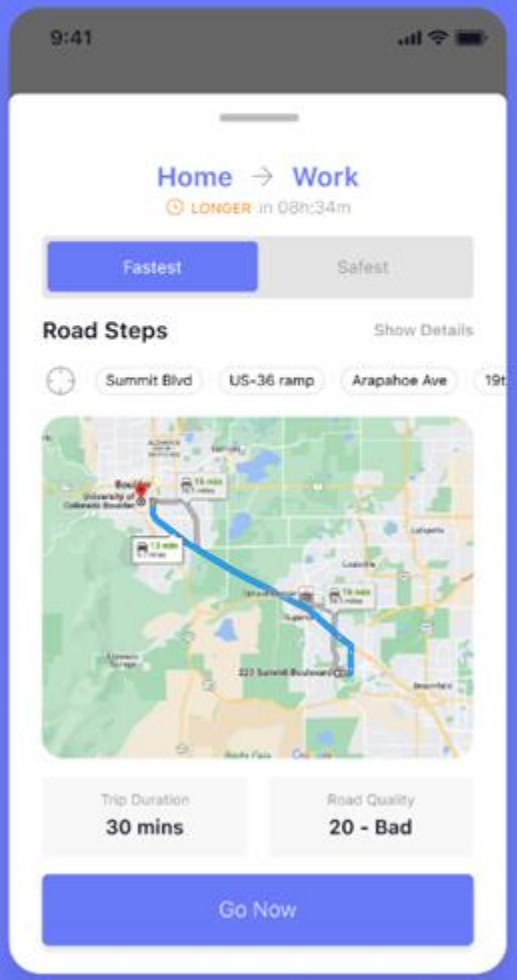
Purenav Trips Assistant

Version 1

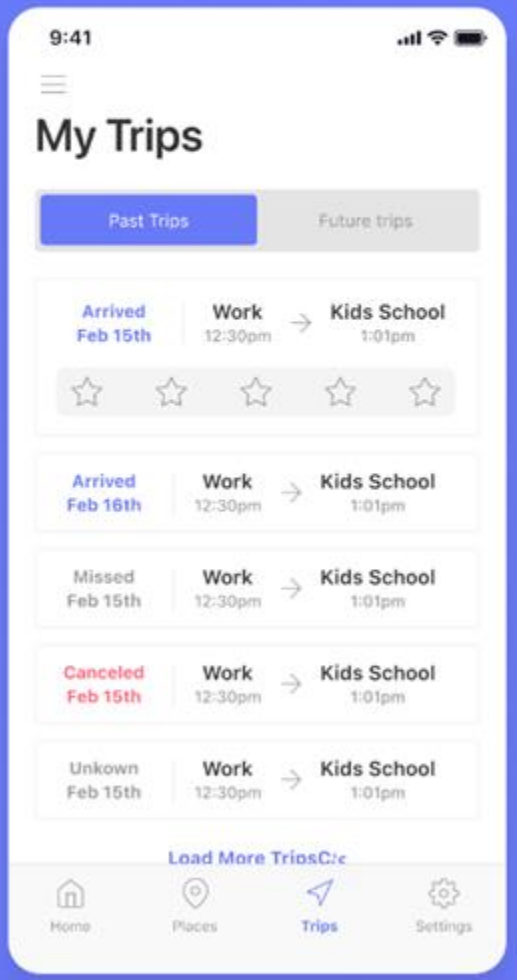
Home



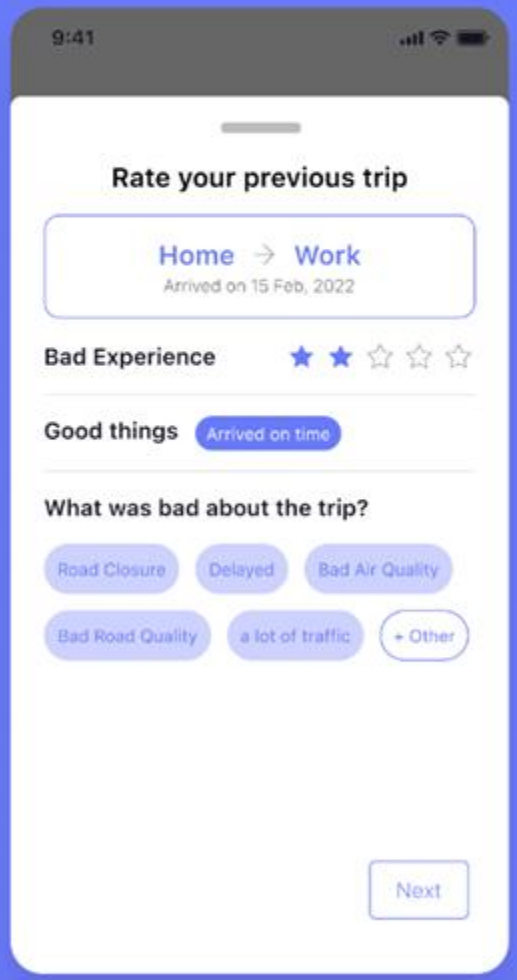
Trip Preview



Past Trips

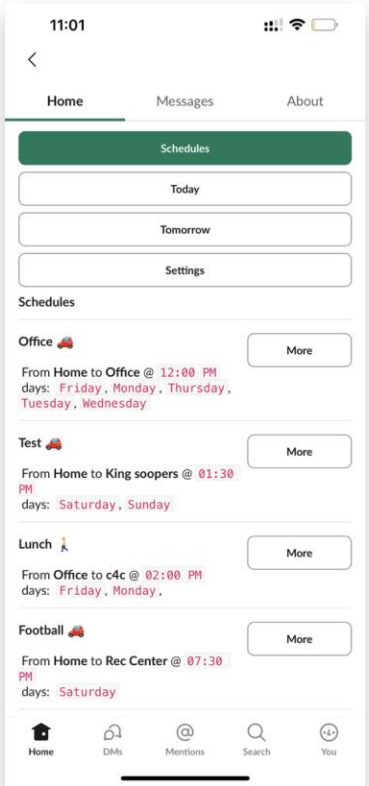


Rate a trip

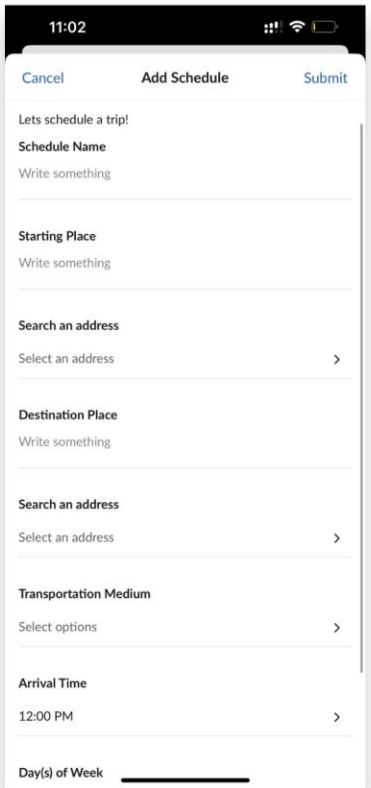


PURENAV

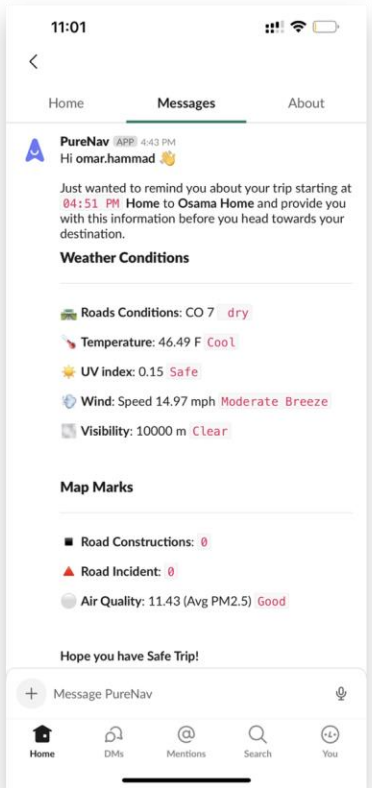
Version 2



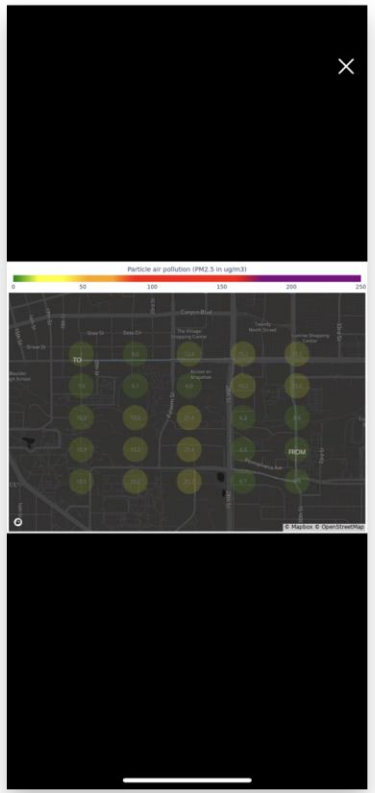
Schedules



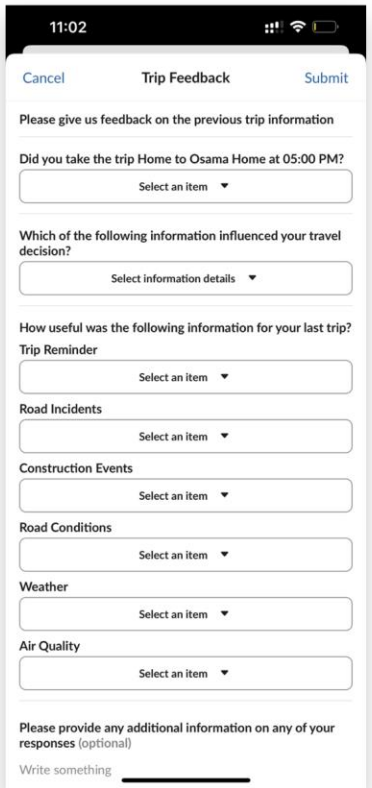
Adding a schedule



Info message

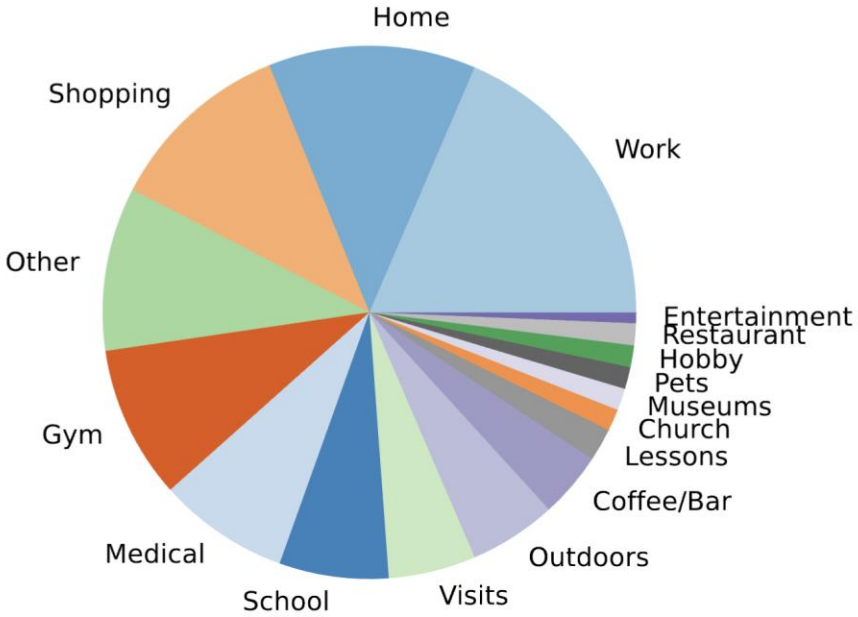


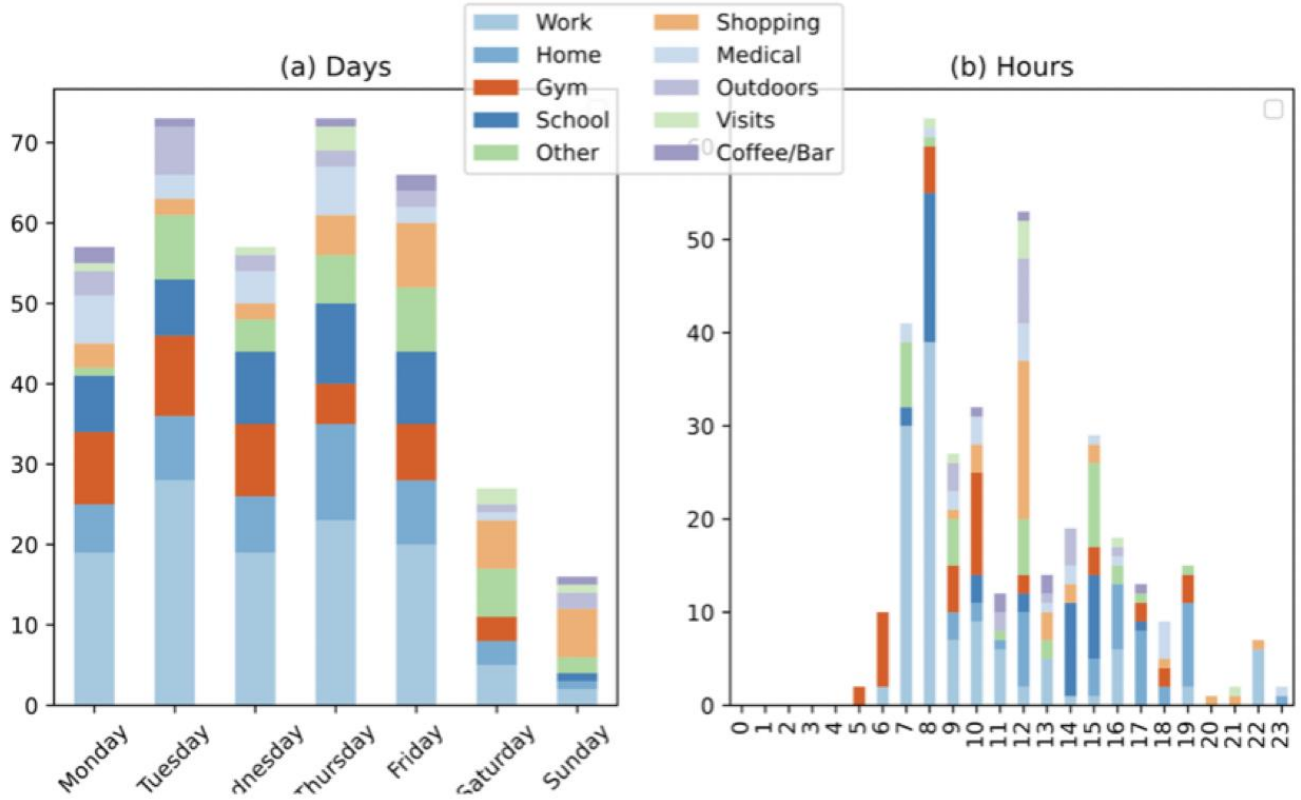
Air Map



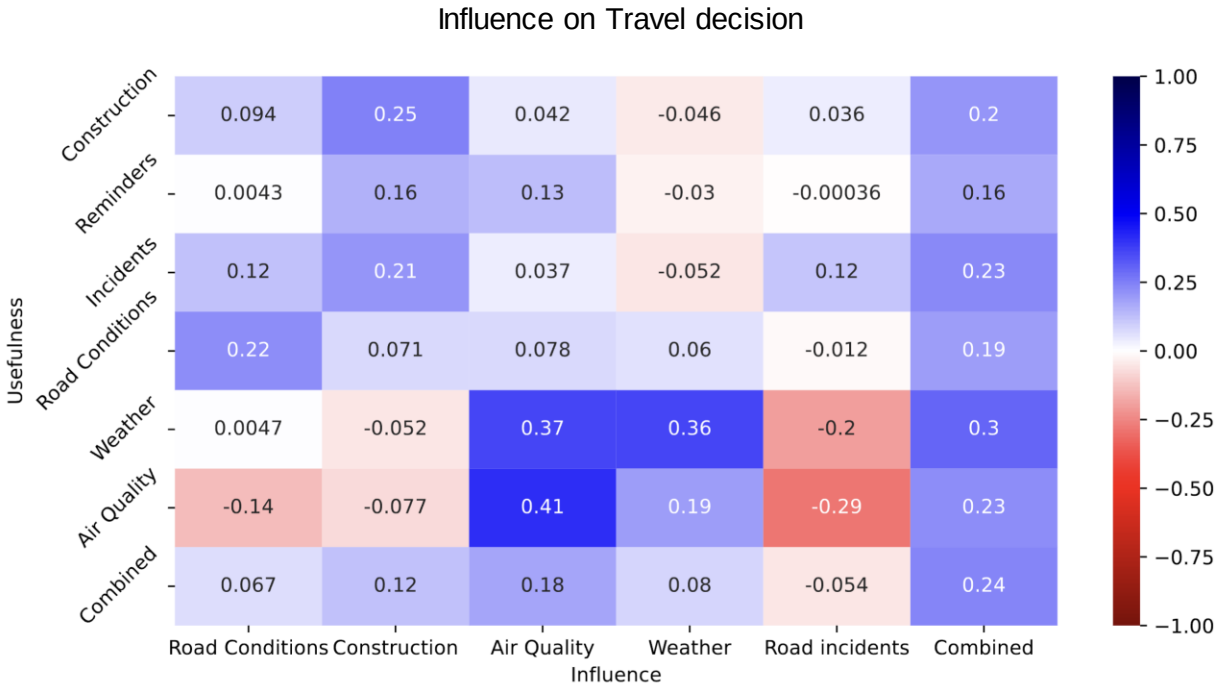
Trip Feedback

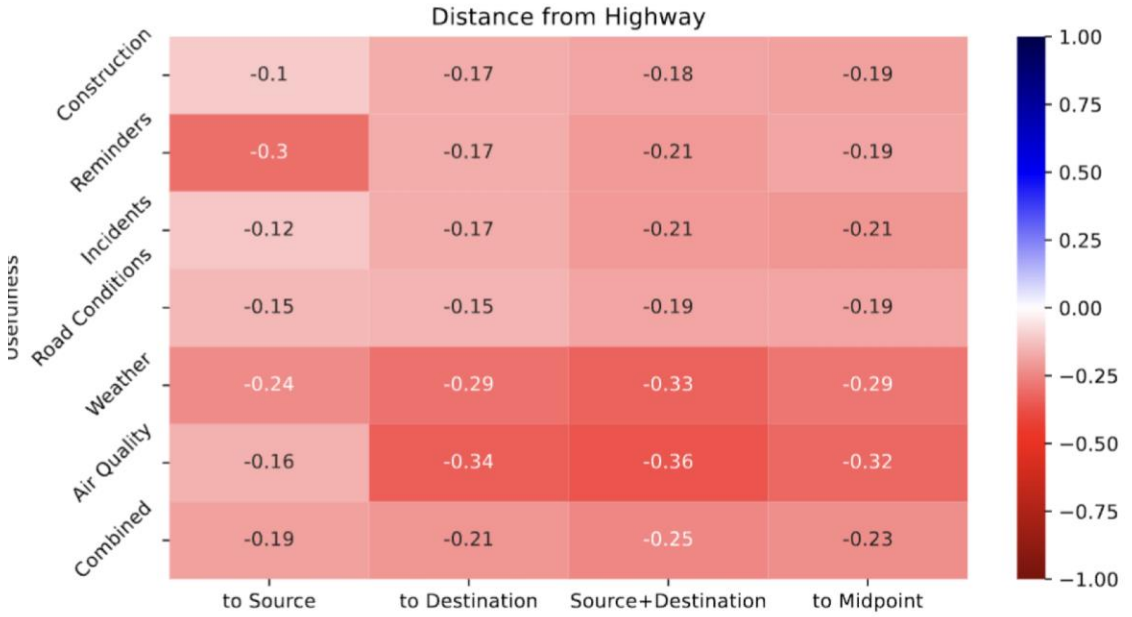
Recurring Schedules days & times



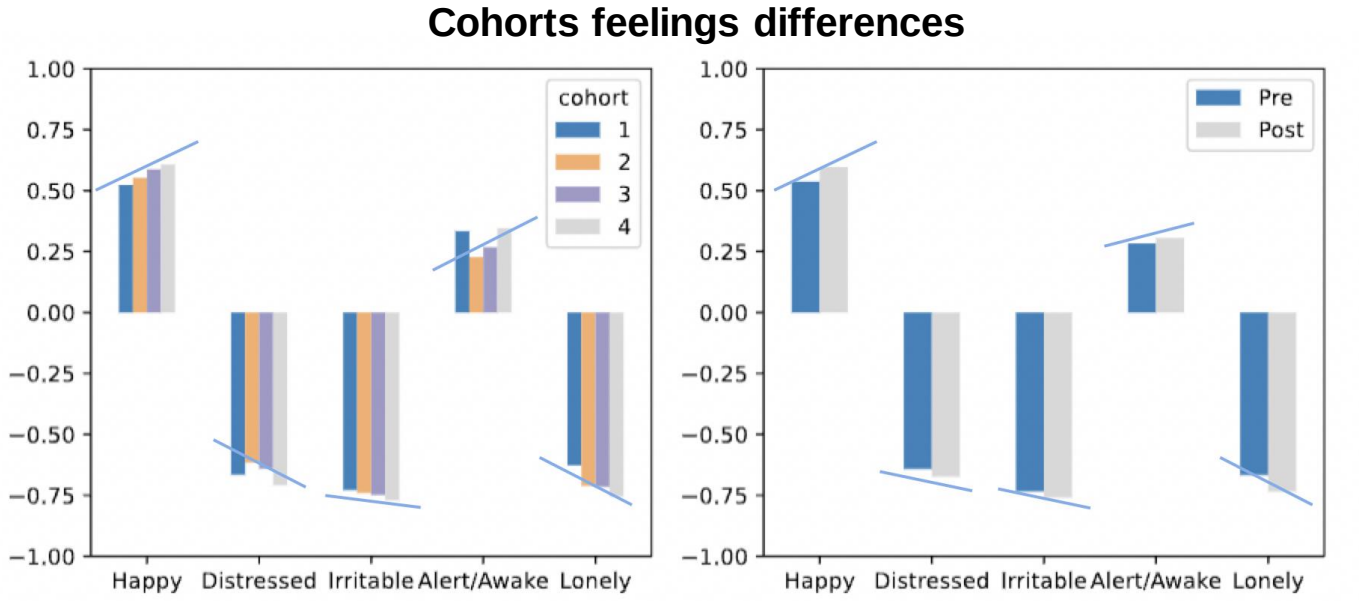


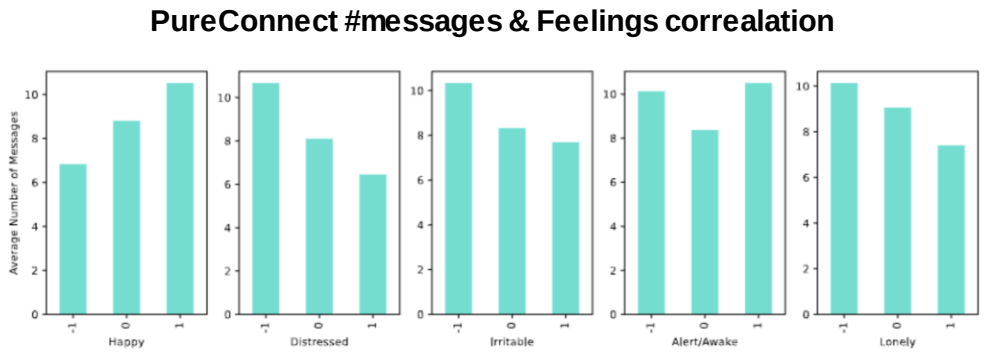
Impacts of perceived usefulness of information

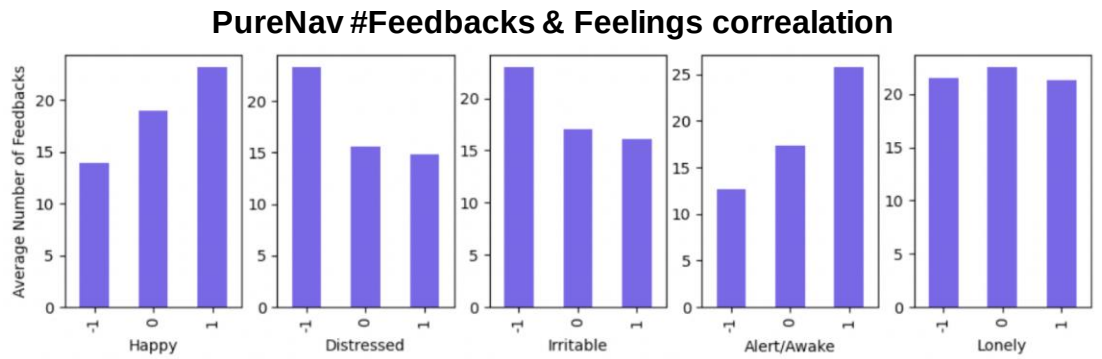




Impacts of intervention on people's wellbeing





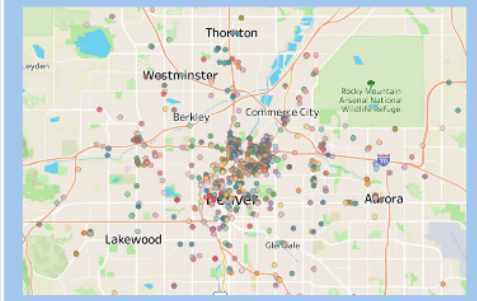


Community Reporting

SJEQ-D Study Summary for Cohorts 1 & 2

The Social Justice and Environmental Quality – Denver (SJEQ-D) study is working to improve indoor air quality in the Denver communities of Globeville, Elyria-Swansea, Cole, and Clayton.

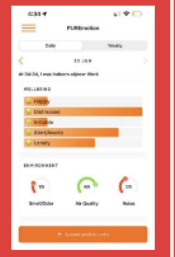
Thank you to the **88 community scientists** from Cohort 1 in winter 2022 and the **97 participants** from Cohort 2 in summer 2022!



Residents have been submitting answers about daily activities and health/wellbeing through PUREmotion, a smartphone app. This map shows where users have been submitting their entries, which helps our research team understand air quality both in the neighborhoods of study as well as in comparison to other parts of the Denver Metro area.

Participants have submitted around **2,000 entries per cohort** in PUREmotion! From that data, we have learned that:

- Participants from Cohort 1 on average rated smell odor as 2.45 out of 5, air quality as 2.37 out of 5, and noise as 2.45 out of 5
- Participants from Cohort 2 on average rated smell odor as 2.31 out of 5, air quality as 2.19 out of 5, and noise as 2.17 out of 5
- Car is the most popular transportation choice, followed by walking
- Dustiness was the top reported air quality concern
- Users reported more allergy symptoms during summer than winter



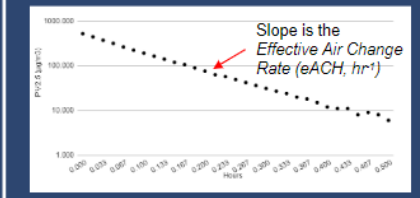
Cohort/Emotion	Cohort 1	Cohort 2
Happy	2.89	2.86
Irritable	0.85	0.91
Distressed	0.96	1.01
Alert/Awake	2.52	2.49
Lonely	0.84	0.76

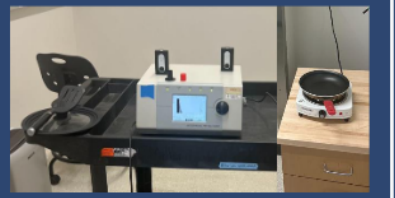
Emotional Index

The table on the left represents the average answer to each emotion reported within the PUREmotion app for each cohort (on a scale where **0** is not at all and **5** is completely). Looking at this information about emotions across different cohorts alongside the reported experiences of construction disruption will help us analyze whether there are any impacts on wellbeing.

DIY Air Cleaner Design for North Denver Communities

The Social Justice and Environmental Quality – Denver (SJEQ-D) study is working to improve indoor air quality in the Colorado communities of Globeville, Elyria-Swansea, Cole, and Clayton. Do-it-yourself (DIY) solutions using box fans and furnace filters taped together are a low-cost option for effective air cleaning. We studied DIY air cleaner designs to optimize air cleaning capacity, reduce cost, and minimize build time and physical size.





The clean air delivery rate (CADR), or the volume of clean air produced per minute by an air cleaner, was measured to assess the effectiveness of different designs. The figure above on the right shows the testing facility.

To measure the CADR, we first estimated the effective air changes per hour (eACH) of particulate matter removal provided by each air cleaner in a test room at the University of Colorado Boulder. We filled a test room with cooking pollution from frying a hamburger in canola oil. We measured how fast each air cleaner design reduced $PM_{2.5}$ concentrations using two Atmotube Pros and calculated the eACH from the slope of the removal curve (see figure above).

We then calculated CADR for each design: **CADR = Test Room Volume [1366 ft³] x eACH [hr⁻¹] / 60 [min/hr]).**

We tested six air cleaner designs with 20x20" MERV13 filters: a 4-filter cube, a 2-filter triangle, and 1-filter designs with filters of differing depths (4", 2", 1"). A fan shroud was used in some designs, intending to improve efficiency. In the table below we compare CADR, ease of build, size, and cost of our designs to determine the best one for North Denver communities. Initial costs include the price of the fan ($49) and filters, and annual costs include the price of changing the filters every 6 months.

	1-MERV13 Filter, 20x20x1" (shroud)	1-MERV13 Filter, 20x20x2" (shroud)	1-MERV13 Filter, 20x20x4" (shroud)	1-MERV13 Filter, 20x20x4" (no shroud)	2-MERV13 Filters, 20x20x2" (shroud)	4-MERV13 Filters, 20x20x2" (shroud)
CADR ($PM_{2.5}$) [ft³/min]	108	127	127	149	230	415
Ease of Build	Medium	Medium	Medium	Easiest	Hardest	Hard
Size	Small	Small	Small	Small	Medium	Large
Initial (Annual) Cost ($)	$59 ($20)	$65 ($32)	$72 ($46)	$72 ($46)	$81 ($64)	$113 ($184)
CADR/Initial Cost [ft³/min-$]	1.8	2.0	1.8	2.1	2.8	3.7
CADR/Annual Cost [ft³/min-$]	5.4	4.0	2.8	3.2	3.6	2.3

OPTIMAL AIR CLEANER DESIGN

We chose the 1-filter design using a 20x20x4" MERV13 filter and no fan shroud. The 1-filter designs are less time consuming to build, take up less space in a room, and have lower initial and annual costs. Of the 1-filter designs, the 4" filter depth had the highest CADR. Activated carbon was added to the design to remove volatile organic compounds (VOC's) and ozone.
For comparison, a Coway Airmega AP-1512HH ($197) air cleaner provides a CADR of 233 ft³/min for smoke (1.2 ft³/min-$ CADR/initial cost) with $115/year of filter replacement costs (1.9 ft³/min-$ CADR/annual cost).

Odor Assessment Studies in North Denver

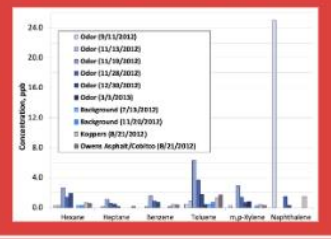
Local residents are key resources in identifying odors. Combining odor identification by residents with chemical monitoring can be useful in identifying odor sources and taking action. Our study goal was to combine these methods to **assess industrial odors in the northern part of the Denver** metropolitan area, which has many factories and two major highways mixed with residential areas. Many health complaints from north Denver residents related to **strong industrial odors have been recorded**, including suffering from burning eyes and throat, headaches, skin irritation, coughing and breathing difficulties.

Based on our work, a regional cooperation to reduce odor problems in North Denver was highly recommended. After completion of our first study in 2016, Dr. Shelly Miller participated in the advisory board to the Denver Department of Public Health and Environment (DDPHE) to develop an **updated odor ordinance**. Instead of relying on an inspector and a scentometer, **they now require specific industries to develop and submit an odor control plan**, including marijuana growers and pet food manufacturers. Also, **a facility must submit a plan if DDPHE has received five or more complaints** from individuals from separate households or businesses within a 30-day period.

Study 1: Tar odors: measuring contaminants and identifying sources

What we did: In response to complaints of a tar odor, we worked with Groundwork Denver on a study in the Globeville community in 2012-2015. Our work was funded by an EPA Environmental Justice Grant. Efforts to identify the odor and its potential sources included a door-to-door survey, meteorological correlations, and air quality sampling for volatile organic compounds (VOCs), sulfur gases, and polycyclic aromatic hydrocarbons (PAHs).

Odor, background, and industrial sample concentrations of compounds detected in air during Study 1.



What we learned: The area has industrial sources of harmful tar odors and we measured high levels of naphthalene, a carcinogen. The study recommended a more detailed investigation to explain the effects of odors in communities, to assess the relationship between odor exposure and well-being, and to understand the effect of odor mixtures.

SJEQ-D NSF Evaluator and Education Team Updates

Community member home visit, Spring 2023

- Goal 1: Understand the personal environment
- Assessment: Zoom observation of the visits
- Observation results
  - Strengths:
    - Community members were comfortable with CU students visiting their house
    - CU students were knowledgeable and able to assist with sensor and app setup to the satisfaction of community members
  - Improvement:
    - CU students were in a hurry and could have benefitted from a bit more time at each house

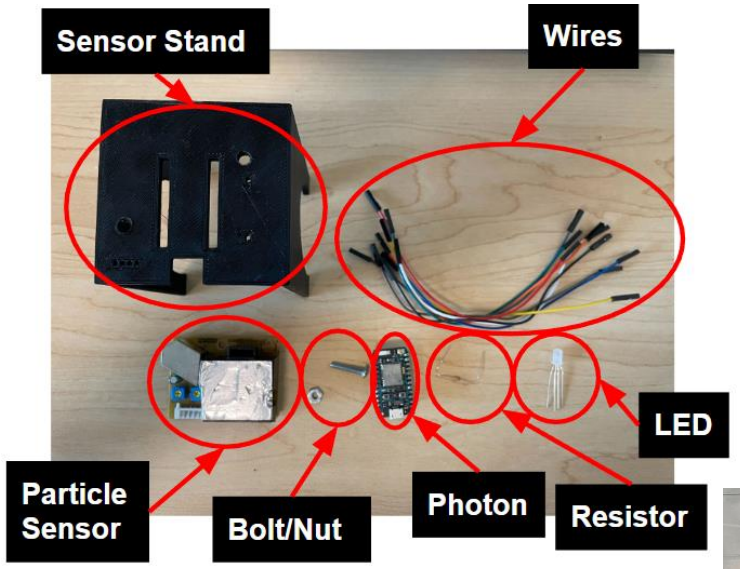
Community Connector Interview, May 2023

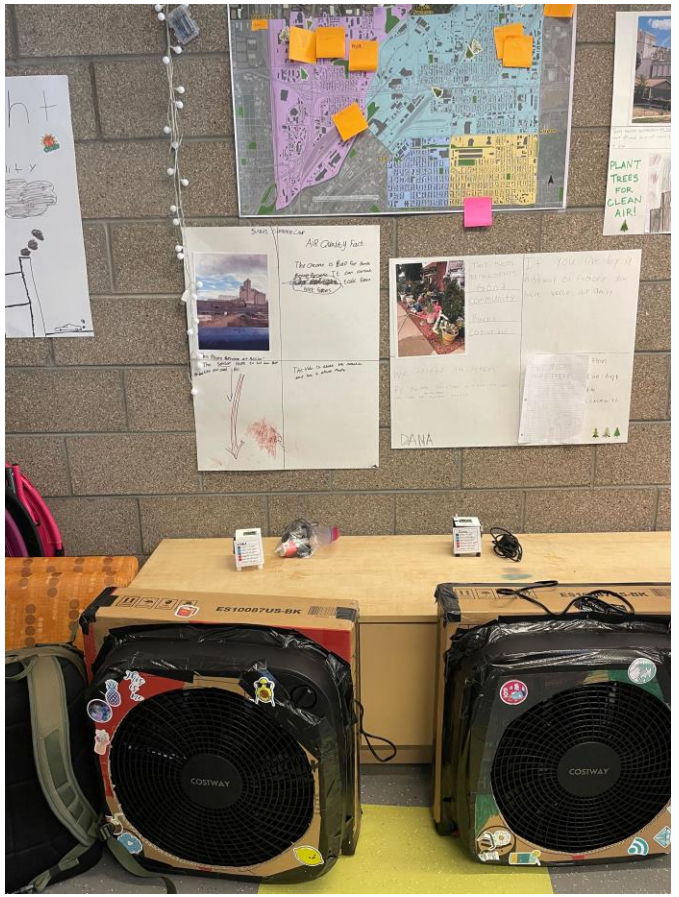
- Goal 2: Mitigate the planned disruption
- Assessment
  - Zoom Interview
- Interview results
  - Successes: Community connector felt the CU team had mitigated the disruption through placing air cleaners in homes and teaching community members how to monitor their air quality
  - Concerns: Community connector worried about ability to continue mitigation after the project ends

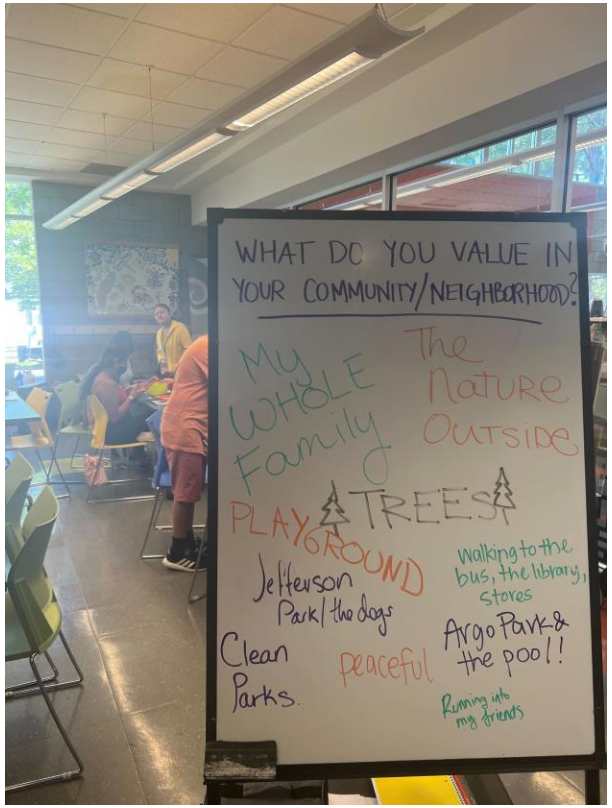
Summer Camp, August 2022

- Goal 3: Educating community members
- Assessment
  - Post-survey, n = 8 participants
- Survey results
  - All responses above 2.25/3 target
  - Highest: I have a better understanding of the tools that are available to measure and solve the problem of poor air quality than at the start of the camp. (2.88/3)
  - Lowest: I have a better understanding of how to communicate science to my community than I did before camp. (2.38/3)

Middle School Summer Camp Outreach







Middle School Summer Camp Outreach

1: What is environmental injustice and how do you describe experiencing it in your community?

Day 1, Tuesday 6/27

1. Introduction to EJ
2. Mapping intro
3. Photo-journaling

2: What tools are available to measure and solve the problem of poor air quality?

Day 2, Wednesday 6/28

1. Introduction to air quality
2. Instrument demos
3. Build particle sensors

Day 3, Thursday 6/29

1. Introduction to IAQ
2. Build air cleaner
3. Air cleaner testing

3: How does science get communicated in a way that makes change happen?

Day 4, Friday 6/30

1. Intro to science communication and policy making
2. Air quality campaign prep
3. Open activities w/ sensors, air cleaners, etc.

Next Steps

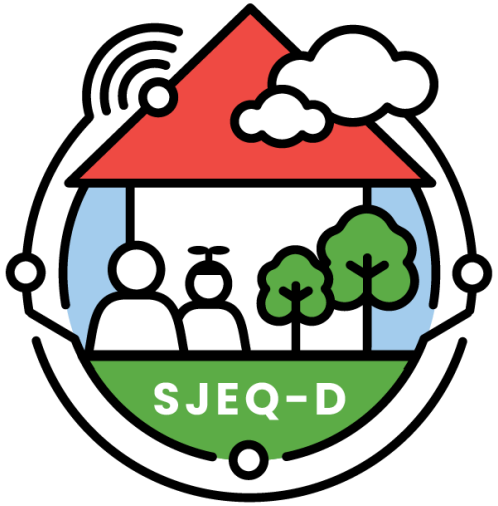
- All cohorts are completed
- Summer camp end of June
- Analyze intervention app use
- Analyze exposure data
  - Weekend vs. Weekday; distance from construction; by neighborhood
- Analyze impact of air cleaner intervention
- Transition use of Socio-Technical System to Community
- Share findings with the community and policy makers
- Pursue linear and spatial modeling between surveys and exposure data – Fall 2023 with CSPH student

Thank you!

Questions?

University of Colorado Boulder

Denver
CU IN THE CITY



https://www.sjeqdenver.com/

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