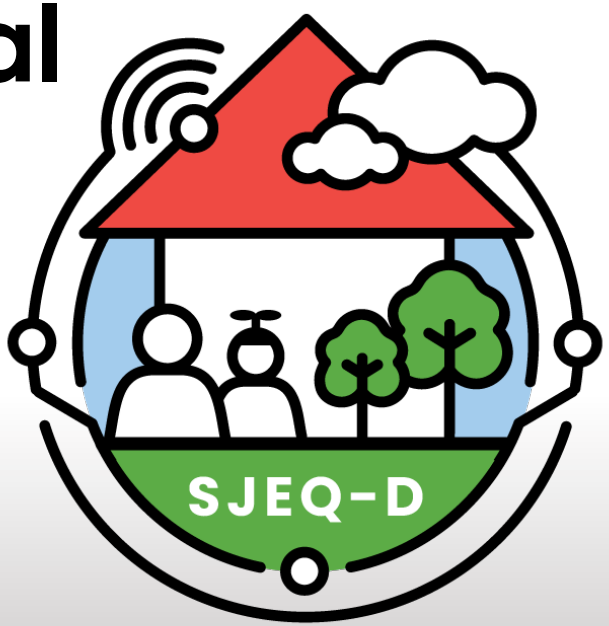
Social Justice and Environmental Quality in Denver (SJEQ-D):

Well-being and Air Pollution Exposure in Environmental Justice Communities



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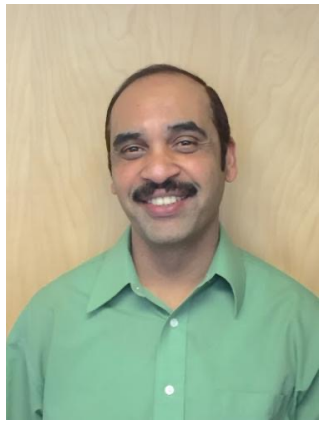

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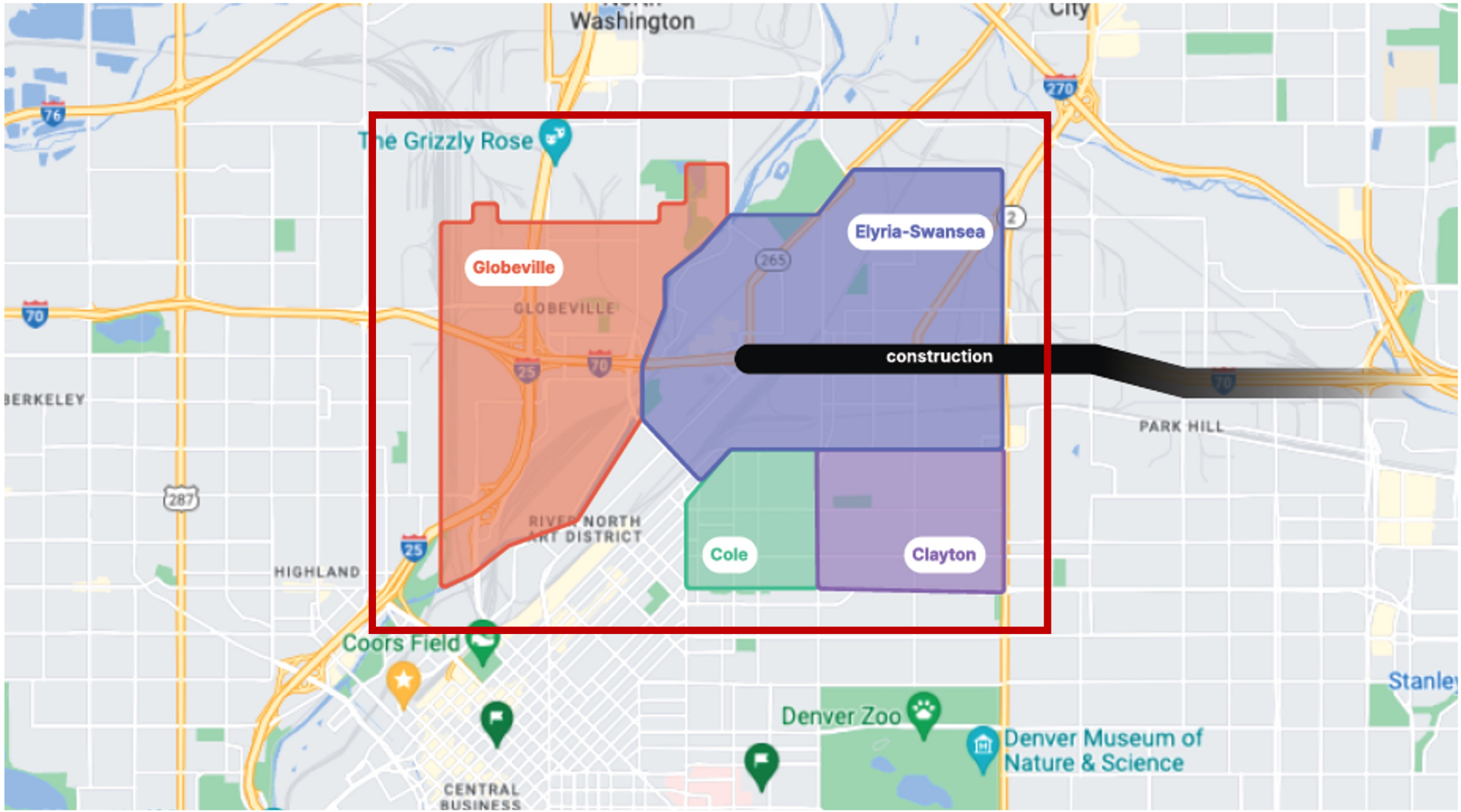
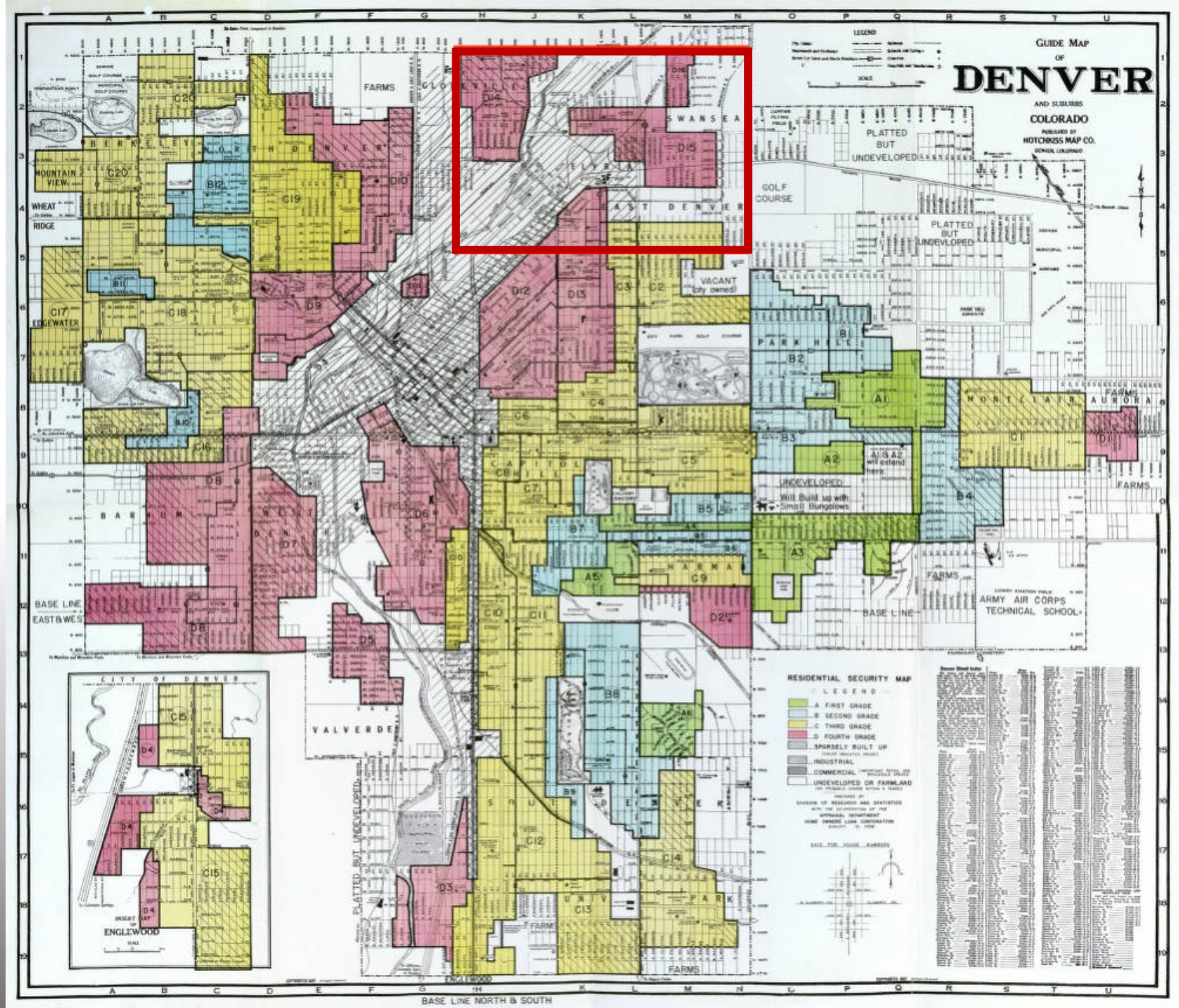
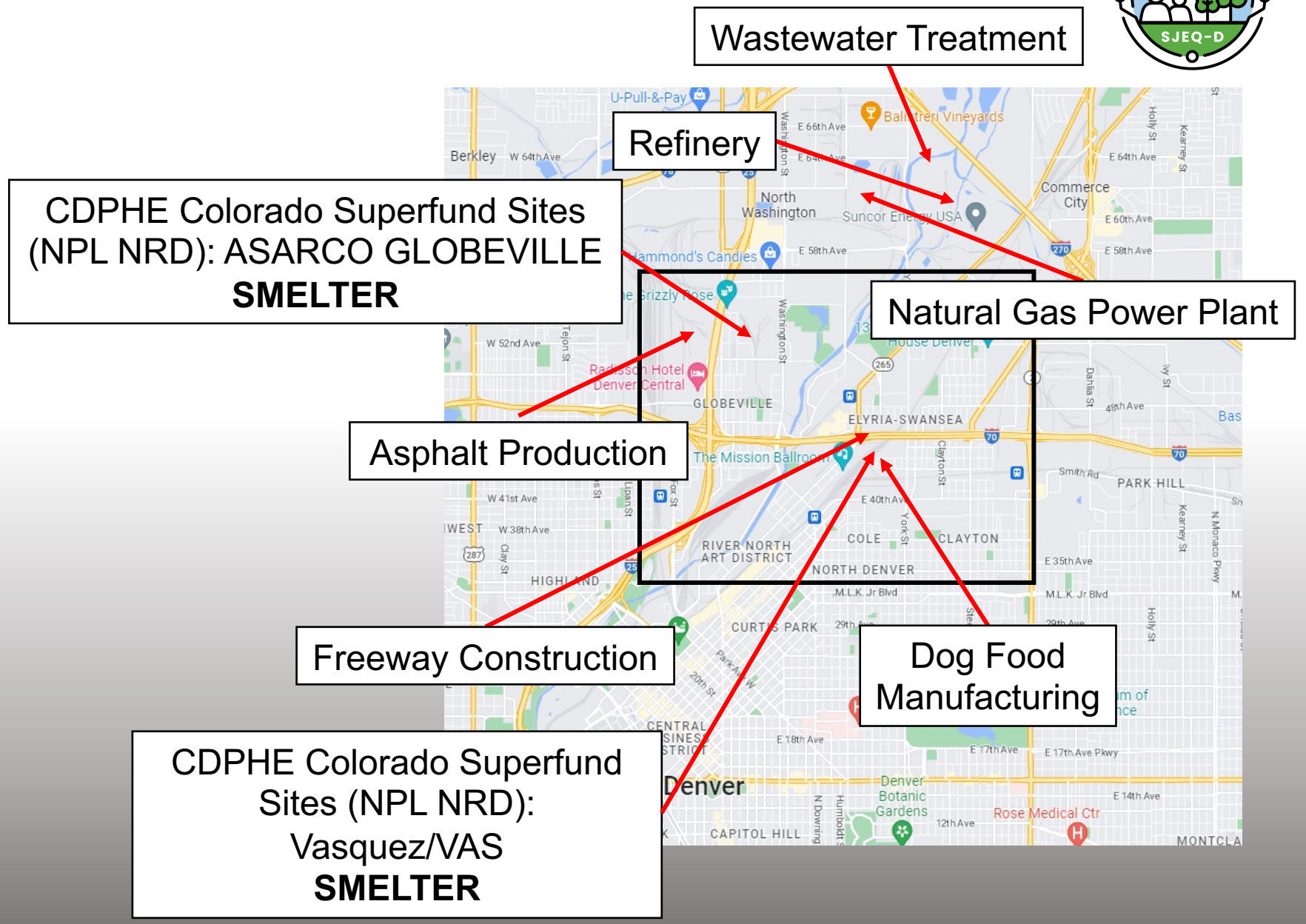
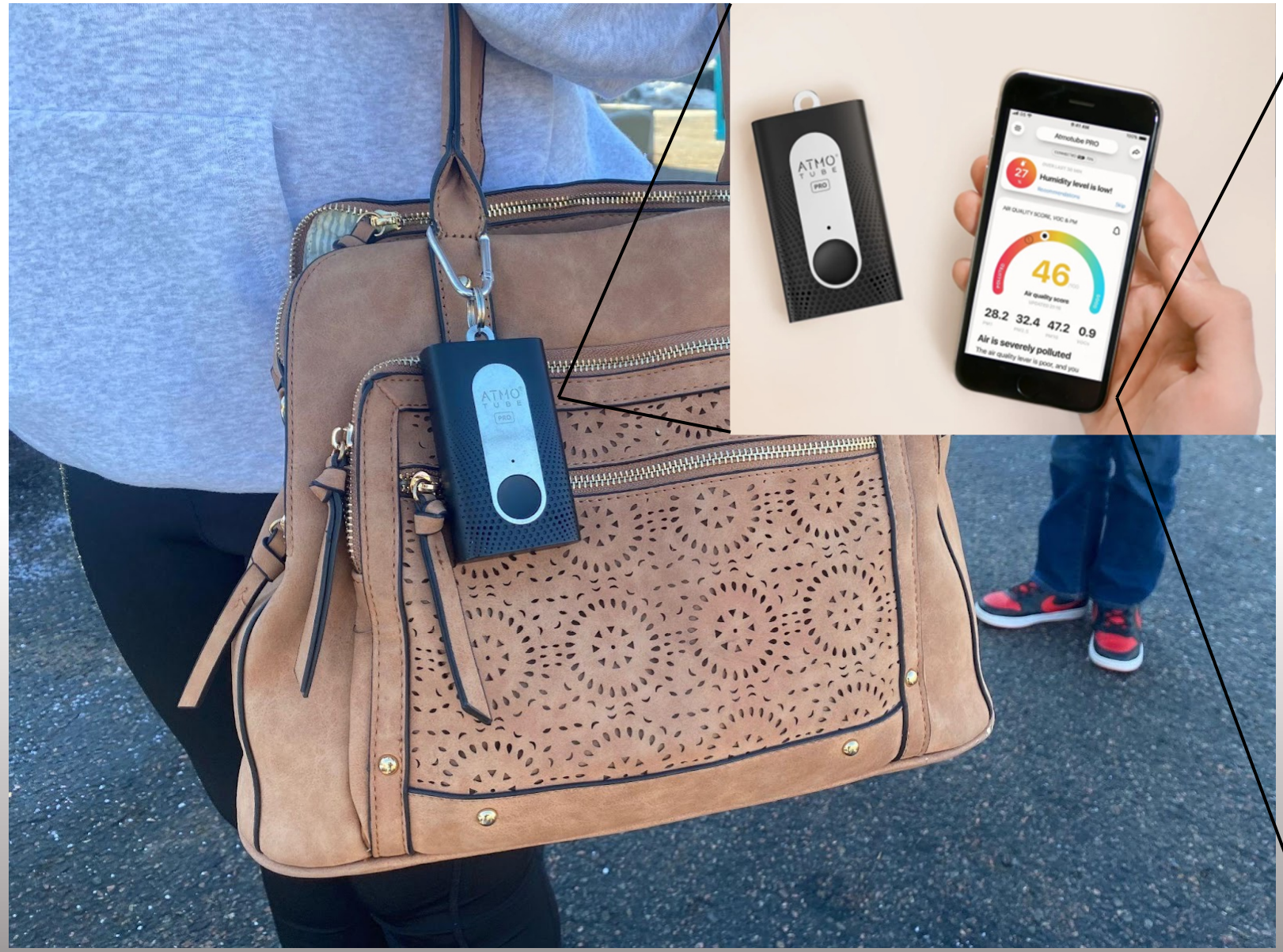

Washington
The Grizzly Rose
Globeville
GLOBEVILLE
Elyria-Swansea
construction
Cole
Clayton
PARK HILL
BERKELEY
HIGHLAND
RIVER NORTH ART DISTRICT
Coors Field
CENTRAL BUSINESS
Denver Zoo
Denver Museum of Nature & Science
Stanley
76
70
25
287
265
270
2


GUIDE MAP
OF
DENVER
AND SUBURBS
COLORADO
PUBLISHED BY
HOTCHKISS MAP CO.
DENVER, COLORADO
LEGEND
PLATTED BUT UNDEVELOPED
GOLF COURSE
PLATTED BUT UNDEVELOPED
VACANT (city owned)
FARMS
SWANSEA
EAST DENVER
BERKELEY
NORTH DENVER
MOUNTAIN VIEW
WHEAT RIDGE
EDGEWATER
PARK HILL
MONTCLAIR
AURORA
CAPITOL HILL
BARNUM
WEST COLFAX
HARMAN
VALVERDE
UNIVERSITY PARK
SOUTH DENVER
A1 & A2 will extend here
UNDEVELOPED
Will Build up with Small Bungalows
BASE LINE EAST & WEST
BASE LINE
ARMY AIR CORPS TECHNICAL SCHOOL
CITY OF DENVER
INSERT MAP OF ENGLEWOOD
RESIDENTIAL SECURITY MAP
LEGEND
A FIRST GRADE
B SECOND GRADE
C THIRD GRADE
D FOURTH GRADE
SPARSELY BUILT UP
INDUSTRIAL
COMMERCIAL
UNDEVELOPED OR FARMLAND
BASE LINE NORTH & SOUTH

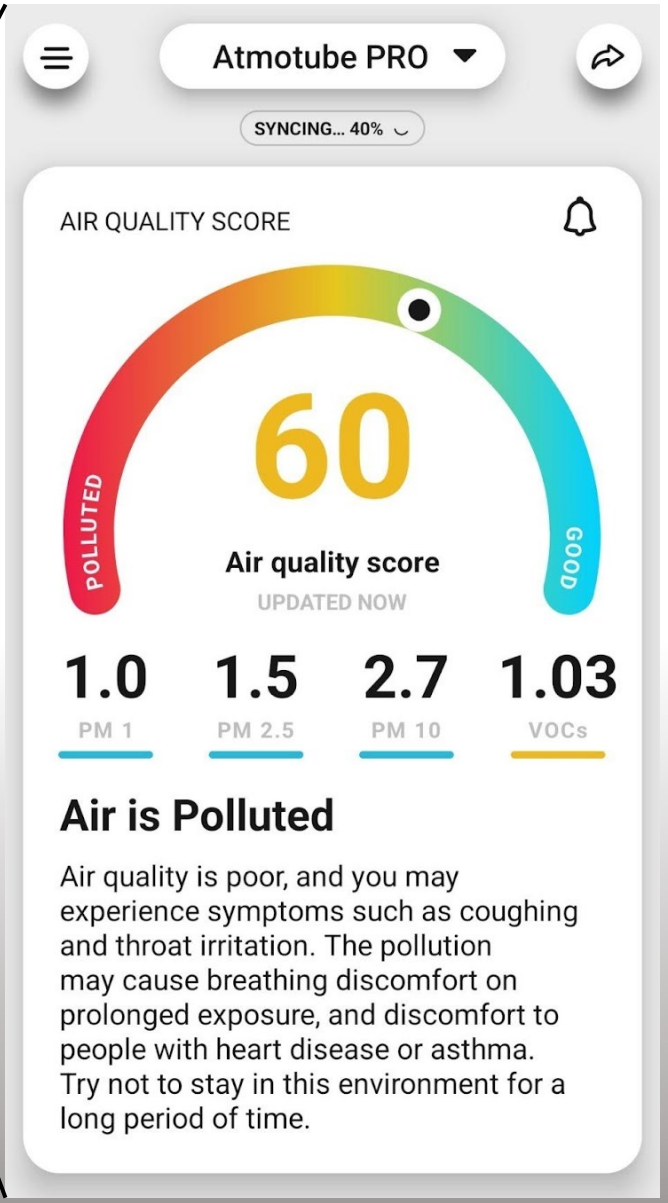
Motivation

- 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




ATMO TUBE PRO

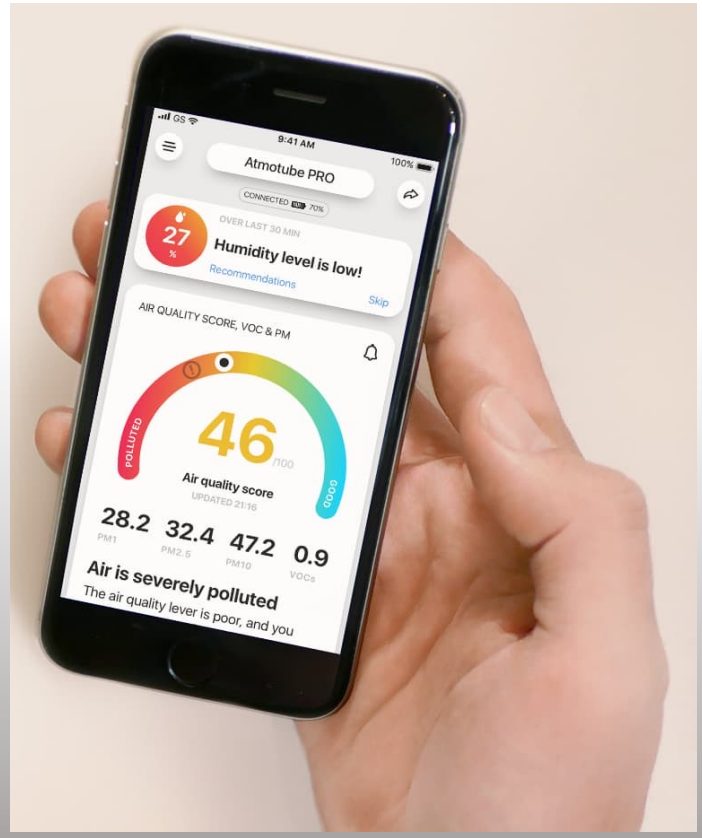
ATMO TUBE PRO
Atmotube PRO
27
Humidity level is low!
46
Air quality score
28.2 32.4 47.2 0.9
Air is severely polluted


Atmotube PRO
SYNCING... 40%
AIR QUALITY SCORE
POLLUTED
GOOD
60
Air quality score
UPDATED NOW
1.0
PM 1
1.5
PM 2.5
2.7
PM 10
1.03
VOCs
Air is Polluted
Air quality is poor, and you may experience symptoms such as coughing and throat irritation. The pollution may cause breathing discomfort on prolonged exposure, and discomfort to people with heart disease or asthma. Try not to stay in this environment for a long period of time.

Atmotube Interviews

Air Quality Sensors Build Pollution Exposure Awareness:

- Rationales for joining study included seeking a baseline understanding of exposure, being a community scientist, or being a health-concerned activist
- Participants wanted to use the Atmotube to measure contamination and get real-time data to know just how bad the air was, conduct community science, and investigate a pollution-related health concern
- 71% of participants said the main benefit of carrying the sensor was building awareness about air pollution exposure in relation to health
- Participants found value in sensor due to increased consciousness about invisible sources of air pollution



Air Quality Sensors Validate/Invalidate Residents' Sensory Experiences

- Participants were able to access and understand sensor data from the Atmotube app regardless of scientific literacy
- Color-coded air quality visuals in the app helped participants without prior air quality knowledge understand their data
- 50% of participants used the app's "air quality score" to frame their understanding of air pollution exposure

Atmotube Interviews

Community Science Experimentation:

- Participants conducted two types of self-directed experiments with their sensors:
  - General exploratory experiments that revealed unexpected sources of poor air quality
  - Experiments performed with the intent of validating specific concerns

Example: An Elyria-Swansea resident first explored the conditions in their backyard greenhouse, noting a rise in temperature. Then they started to notice that when they smoked marijuana inside, their air quality significantly degraded. This was a surprise to the resident, as they thought marijuana smoke was safer than tobacco smoke.

Air Quality Sensors Support Decision Making/Behavioral Change

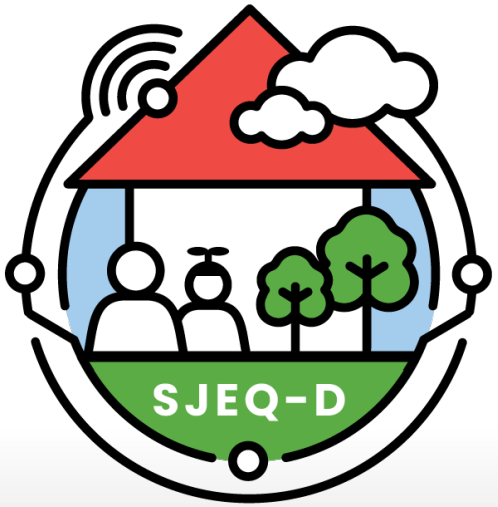
- 50% of participants adopted exposure mitigation behaviors when identifying poor air quality with the sensors, and were often able to identify sources of poor air quality (e.g., cleaning products, smoking)
- Behavior changes included: running humidifiers/air cleaners, running the house fan, cleaning ducts, replacing HVAC filters, closing windows, installing better windows
- 40% of participants adopted protective behaviors, such as going outside when outdoor air was better than indoor air, traveled to locations in neighborhood with lower air pollution

Atmotube Interviews

Air Quality Sensor Limitations:

- 14/38 residents did not report behavior changes, reasons included measuring good air quality, feeling powerless to change the situation
- 6/38 residents expressed not knowing what to do to improve air quality
- Four residents reported that they wanted what the sensor alone could not provide, specific guidance on next steps to improve air quality

Thank you!



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Award No. 195222

SJEQ-D Study Collaborators

External Outreach and Collaboration

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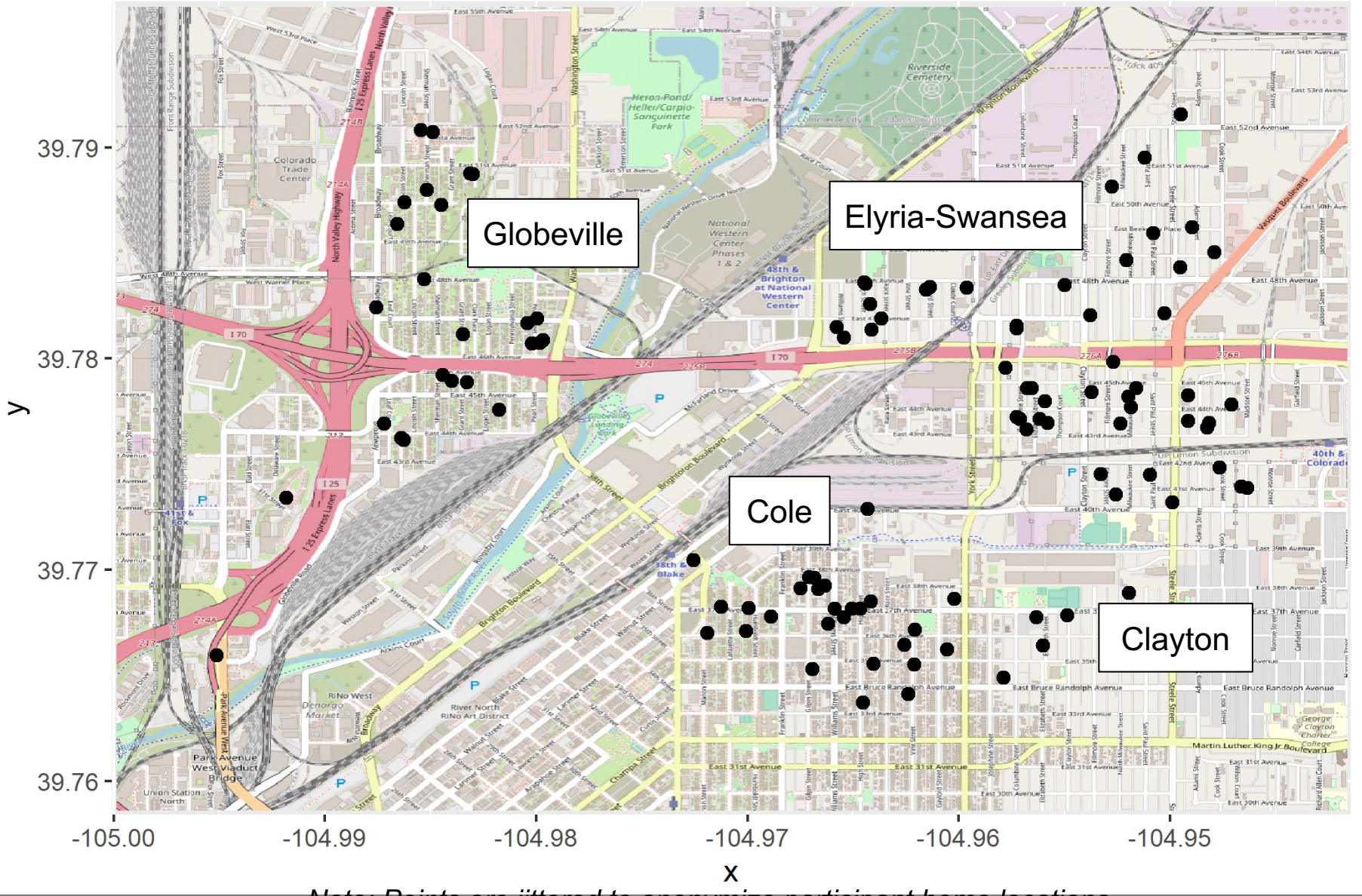
  - Erika Delzell
  - Rey Gallegos
- Green Latinos
- Growhaus
- Cultivando
- Compost Colorado
- GES Coalition
- Swansea Elementary
- Garden Place Elementary
- DSST Cole School
- Valdez-Perry Library
- Denver DPHE
- Colorado DPHE
- CDOT
- Denver City Council, D9
- CO School of Public Health
- CSU
- Birdseed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

Participant Spatial Distribution



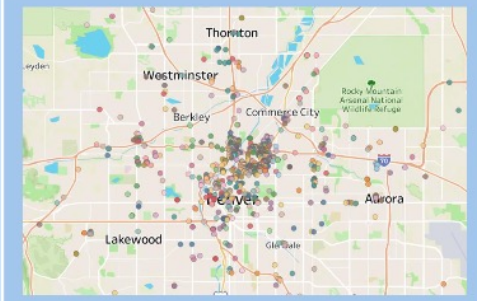
Note: Points are jittered to anonymize participant home locations

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

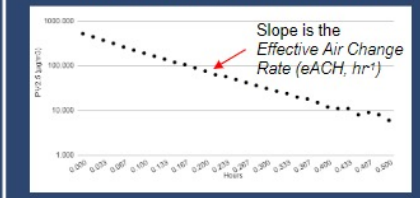
Cohort/Emotion	Cohort 1	Cohort 2
Happy	2.89	2.86
Irritable	0.85	0.91
Distressed	0.96	1.01
Alert/Awake	2.52	2.49
Lonely	0.84	0.76

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

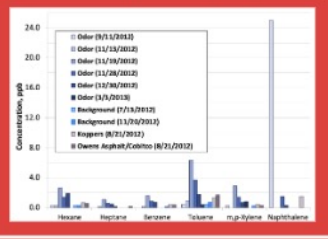
Local residents are key resources in identifying odors. Combining odor identification by residents with chemical monitoring can be useful in identifying odor sources and taking action. Our study goal was to combine these methods to **assess industrial odors in the northern part of the Denver** metropolitan 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.