Increasing Our Understanding of PM2.5 Particulate Pollution Monitoring Through a Network of Low-Cost Air Quality Monitors

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March 22, 2022

Overview

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- Environmental Impact on Health
- Overview of US Ignite Air Quality Monitoring Project
- Conclusions & Lessons Learned
- Future Directions
- Discussion

Introductions

Chief of Air Pollution Outreach
Cleveland Department of Public Health
Division of Air Quality (CDAQ)

Professor, Dept. of Electrical, Computer, and Systems Engineering and Faculty Director, ISSACS
Case Western Reserve University

Executive Director
Institute for Smart, Secure and Connected Systems (ISSACS)
Case Western Reserve University

Environmental Impact on Health

Division of Air Quality Cleveland's Local Air Agency -- Protecting the Air Since 1882

- Responsible for enforcement of the local Cleveland Air Pollution Control Code.
- Serves as an Ohio EPA Delegated Agent for air pollution control for all of Cuyahoga County.
- Ensures that regulated air pollutants are in compliance with local, state, and federal air regulations.

Historical Air Quality conditions

Newburgh Steel Workers, 1893

Rolling Mills, 1890's

Blast Furnace, 1930's

Cleveland Flats, 1930's

Smoke from Steel Factory
(Between 1950's and 1970's)

Cedar Hill Housing, 1972

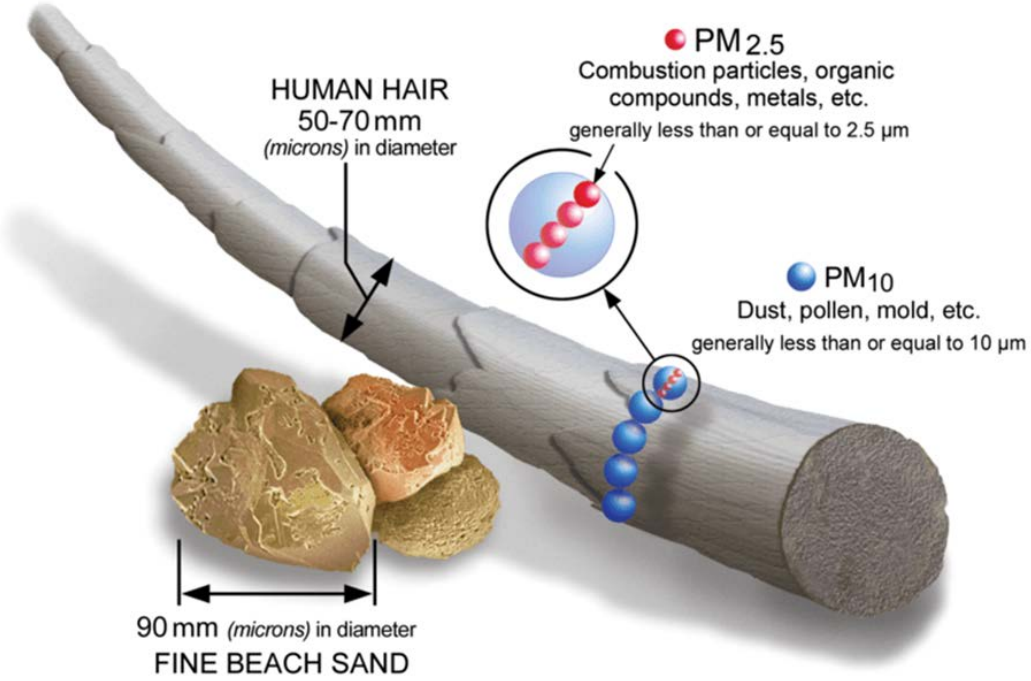
NATIONAL AMBIENT AIR QUALITY STANDARDS

The Six Criteria Pollutants

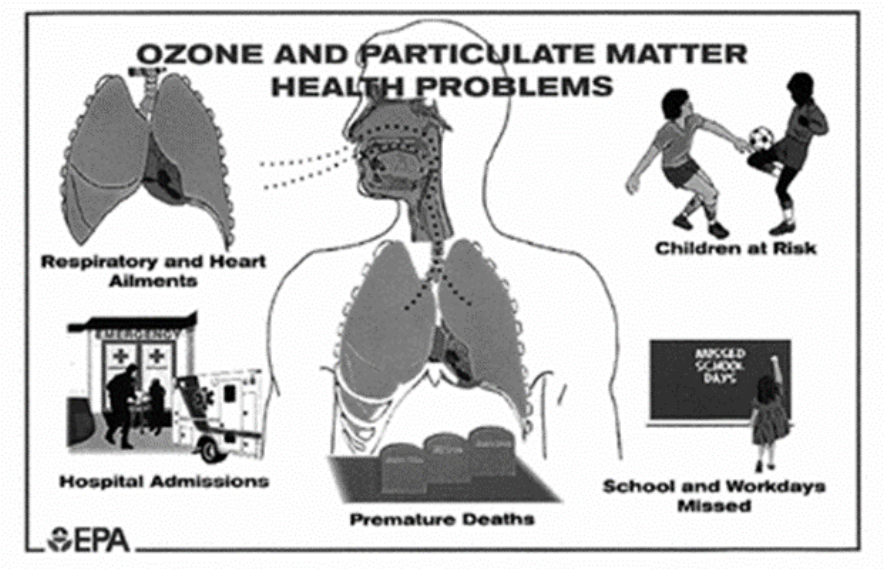
OZONE	• Made up of three oxygen atoms • Occurs in Earth's upper atmosphere (good) and at ground-level (bad) • Ground-level ozone is a harmful air pollutant and the main ingredient in smog
PARTICULATE MATTER	• Mixture of solid particles and liquid droplets found in the air • Can be harmful due to the small size of the solids or droplets • Droplets can be inhaled which may cause serious health problems
CARBON MONOXIDE	• Colorless, odorless gas that can be harmful when inhaled in large quantities • Released when something is burned • Cars, trucks and other vehicles, or machinery that burn fossil fuels are the main sources of outdoor CO pollution
SULFUR DIOXIDE	• Emitted to the air from the burning of fossil fuels by power plants and other industrial facilities • Can be harmful to the human respiratory system and make it difficult to breathe • Reacts with nitrogen dioxides, water, and other chemicals to create acid rain
NITROGEN DIOXIDES	• Part of a group of highly reactive gases known as nitrogen oxides (NOx) • Primarily emitted from the burning of fuel and forms from emissions from cars, trucks, buses, off-road equipment, and power plants • Reacts with other chemicals in the air forming particulate matter, ozone, and acid rain
LEAD	• Emitted into the air from ore and metals processing and piston-engine aircraft operating on leaded aviation fuel; highest concentrations found near lead smelters • Can negatively affect the nervous system, kidney function, immune system, reproductive and development systems, and the cardiovascular system

78% reduction in Criteria Air Pollutants since the 1970 Amendment to the Clean Air Act

Particulate Matter



Health Impacts



- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis
- decreased lung function
- premature death
- irregular heartbeat
- heart attack
- premature death for those with heart or lung disease

Air Quality Index

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range:	*..air quality conditions are:*	*...as symbolized by this color:*
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

US Ignite Air Quality Monitoring Project

https://www.us-ignite.org

US Ignite is accelerating the smart city movement – and creating value for an entire ecosystem – by guiding communities into the connected future, creating a path for private sector growth, and advancing technology research that's at the heart of smart city development.

- DigitalC is the Cleveland partner for US Ignite
- Cleveland is a founding member of US Ignite Smart Gigabit Communities
- US Ignite Works closely with National Science Foundation (NSF)
- Smart Cities Connect Conference - Columbus, Ohio April 4-7

usignite Opportunity: Air Quality Improvements to Mitigate COVID-19 Deaths

Air pollution has been shown to increase the death rate from COVID-19 by 8% for each microgram of PM2.5 pollution per cubic meter.

Invitation to communities interested in reducing air pollution by deploying dozens of sensors, analyzing their pollution microclimate, and taking action to mitigate previously unknown sources and otherwise decrease air pollution to participate.

The project consists of deploying and maintaining 50 Tetrad AirU monitors, and using the data captured to improve health outcomes for the region.

Tetrad AirU

https://www.tetradsensors.com

- Indoor or outdoor monitoring - ~$250/ea
- Measures particulate matter (1µm, 2.5µm and 10µm), oxidizing and reducing species, temperature, humidity, location (GPS)
- Transmits data to the cloud through a Wi-Fi connection
- Diameter of approximately 5'' a height of 2 ½”
- “Weatherproof” but not “Waterproof”

Cleveland Partners

digital c

Case Western Reserve University | Institute for Smart, Secure and Connected Systems

cdph
Cleveland Department of Public Health

COLLABORATIVE

Cleveland State University 1964 | CSU TECH Hub

CLEVELAND NEIGHBORHOOD PROGRESS

Cleveland Project Goals

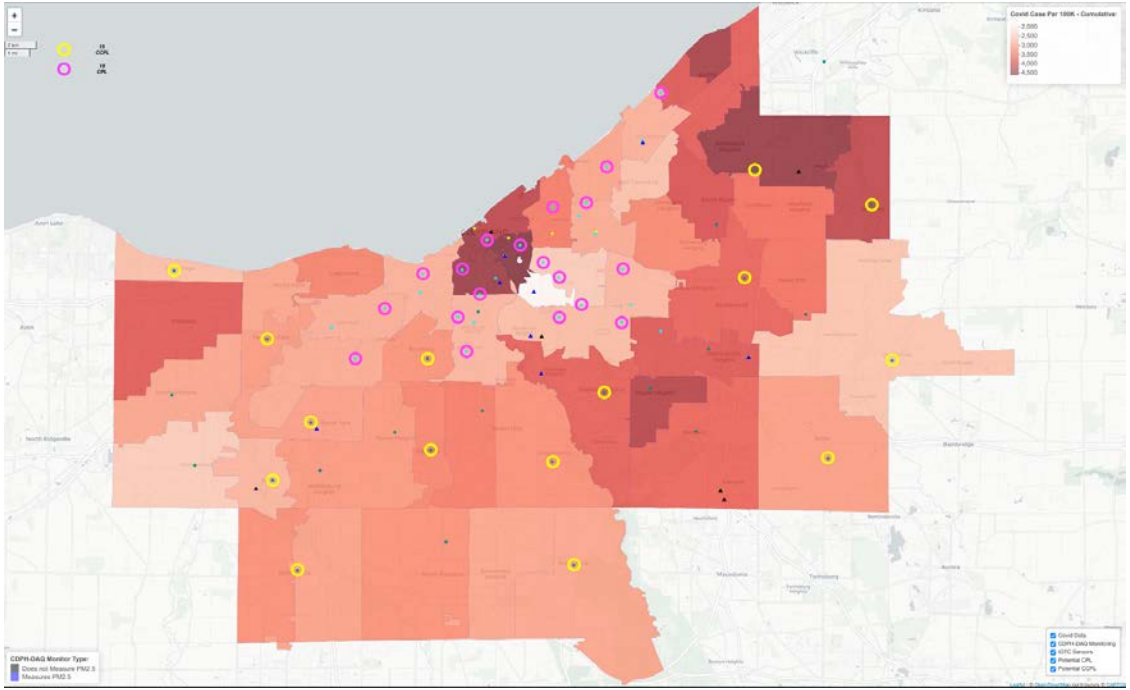
1. Investigate the correlation of PM2.5 air pollution on the incidence of COVID-19. Share the resulting data and insights to improve public health outcomes and policies.
2. Understand the characteristics of low-cost monitors and how they can add additional information to existing data sources (e.g., EPA monitors) to gain a more detailed understanding of temporal and spatial aspects of Greater Cleveland's airshed.
3. Develop a platform for the collection and analysis of air quality data to support researchers and organizations in their efforts to improve the region's health (e.g., air quality correlation to other social determinants of health, environmental exposure impact on cardiovascular health, maternal health, and infant mortality).

Deployment Methodology

Phased Deployment Strategy

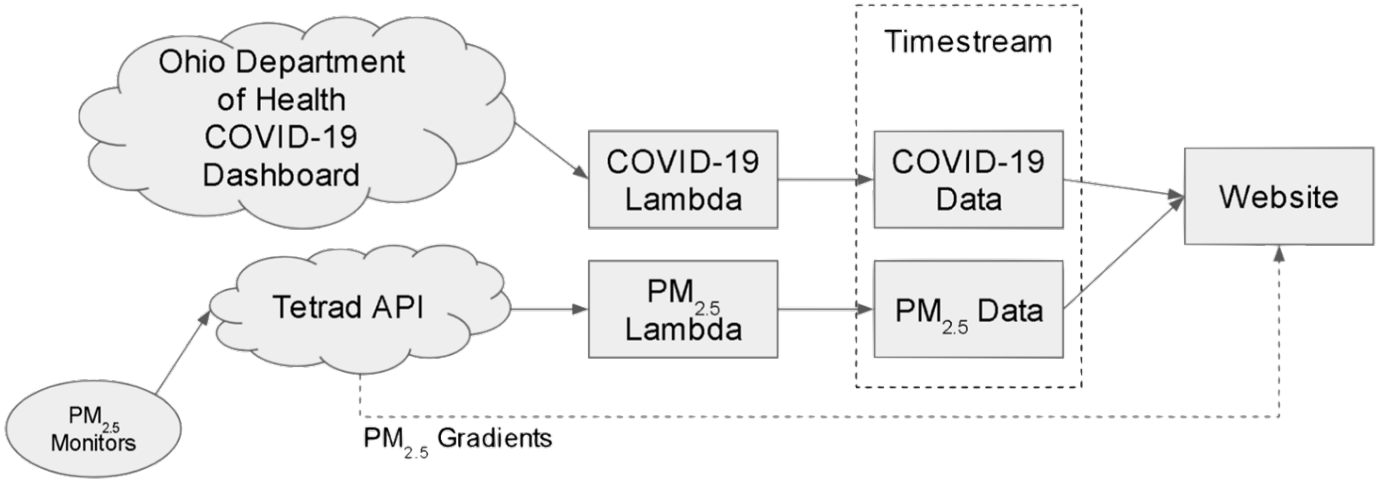
1. **Learning** (5 monitors) - develop familiarity with installing the monitors
    a. (2) Co-located with CDAQ Teledyne T640X (G.T. Craig & Near Road)
    b. (3) DigitalC (MidTown Tech Hive), CWRU, CSU
2. **Scaling** (35 monitors) - coverage: dense (Cleveland) & broad (Cuyahoga County)
    a. Cleveland Public Library (CPL)
    b. Cuyahoga County Public Library (CCPL)
3. **Targeting** (10 monitors) - target neighborhoods with suspected high PM2.5
    a. Cleveland Neighborhood Progress recruiting

Deployment Plan - Phases 1 & 2

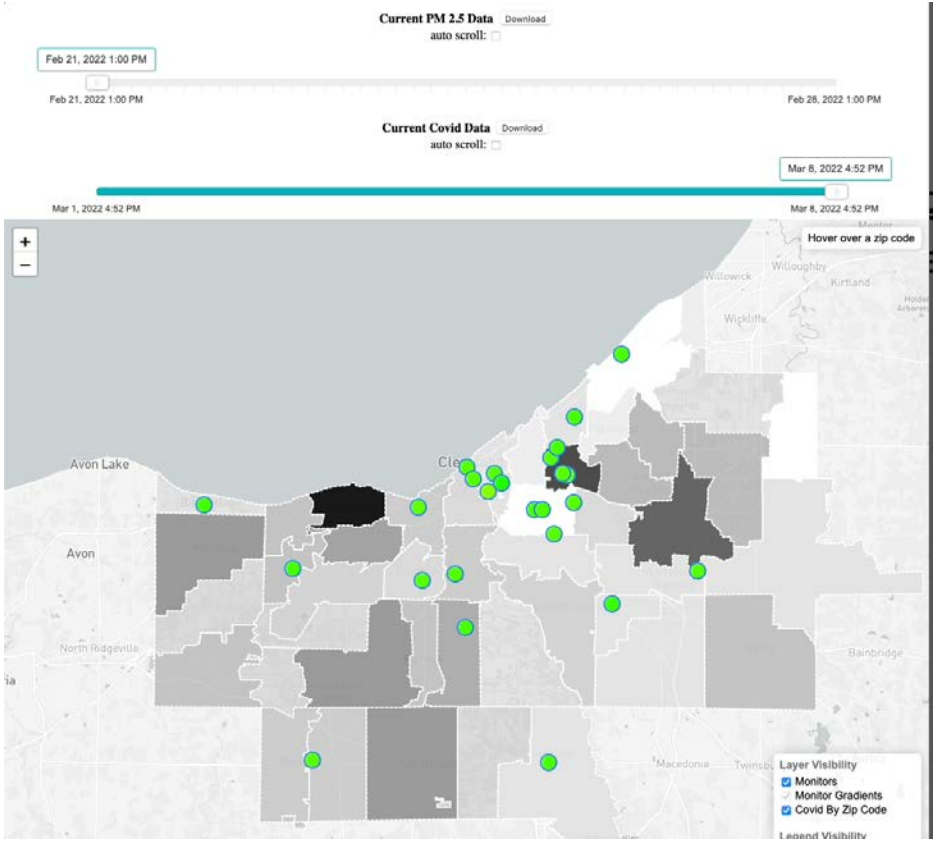


Data Pipeline & Platform

Work of Andrew Szabo (MS CS '21)



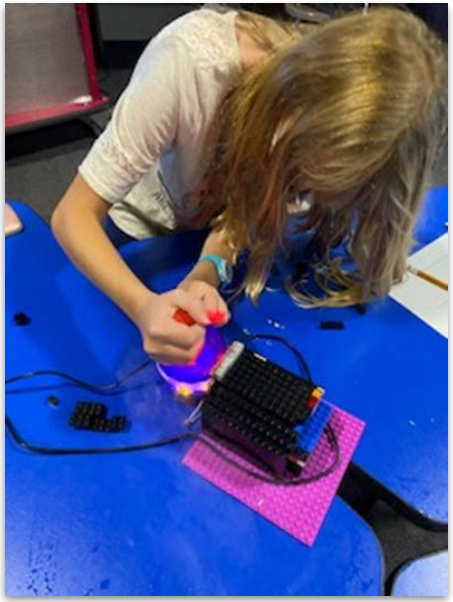
Platform Demo



Conclusions & Lessons Learned

- This initial study confirmed that lower cost monitors can be effectively deployed in a wide geographic area
- Increased temporal and spatial resolution provides data that enhances our understanding of Cleveland's airshed
- Data visualization provides a means for quickly assessing the temporal and spatial patterns of PM2.5 across the sensing area
- Initial analysis established the feasibility of studying correlations between PM2.5 concentrations and COVID-19 infections
- Installation challenges include:
  - Location - Tetrad monitors are Weatherproof not Waterproof
  - Power - availability of outdoor AC power
  - Wi-Fi - deployment and stability

Air Sensor Lego Workshop



Future Directions

- Continuing to deploy sensors; collaborating on related activities

- Need to overcome some of the challenges observed in the initial study, looking for lower cost monitors that:
  - Can operate over extended time periods on battery power
  - Are Waterproof
  - Do not rely on Wi-Fi or require a Cellular Data Plan
- Looking at PM2.5 monitors with additional sensing capabilities (e.g. Ozone)
  - With Low Power Wide Area Network (LPWAN) options
    - Looking specifically at Long Range WAN (LoRaWAN) to help manage power consumption and assist with device deployment

Ongoing Sensor Opportunities

- Continue to partner with community organizations to how air sensors would be a benefit to their constituents
- Build on collaborations with schools to utilize air sensors as a tool to educate on air pollution, data collection, citizen science, and environmental justice
- Offer Air Sensor Lego workshop to community organizations, schools, summer camps..and whoever else is interested!

Discussion