NICO DAIYEGA

ARGONNE NATIONAL LABORATORY
CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR (CBRN) DETECTION AND ANALYSIS
STRATEGIC SECURITY SCIENCES DIVISION
POSTDOCTORAL APPOINTEE

EMERGENCY PHASE, MECHANICALLY INDUCED, PARTICLE RESUSPENSION AND RESUSPENSION STABILIZATION

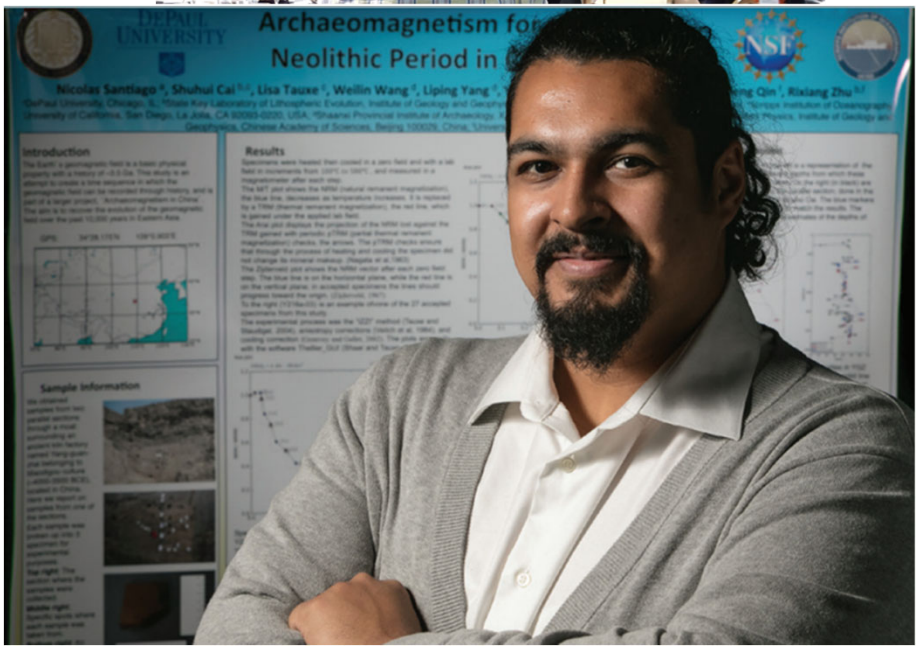
UIUC Physics - Careers Seminar

Nico Daiyega PhD

April 4, 2024

PAST RESEARCH

- Moraine Valley Community College
- DePaul University
  - Baryonic Acoustic Oscillations
- University of California San Diego
  - "Archaeomagnetism for the Middle Neolithic Period in Central China"
    - 2016 SACNAS National Conference – Outstanding Research Presentation Award
    - 2016 DePaul Student Showcase – Poster Presentation Award
    - 2017 ILSAMP Conference – Outstanding Oral Presentation Award

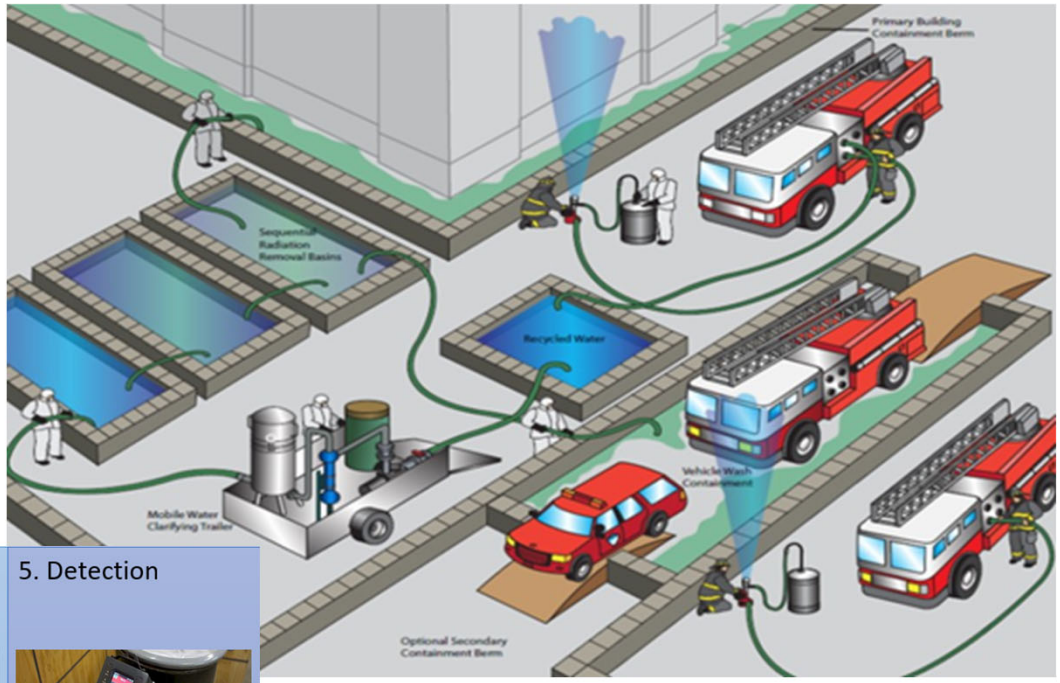


PAST RESEARCH

- DePaul University Study Abroad
  - Kyoto, Hiroshima, and Nagasaki

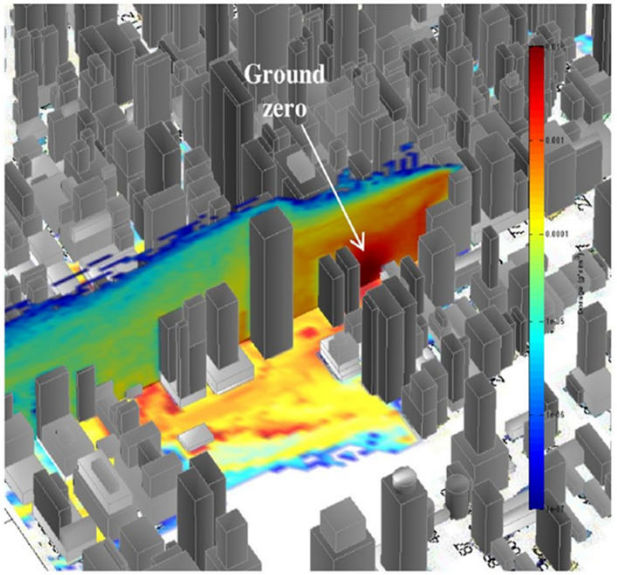
PAST RESEARCH

- Integrated Wash Aid Treatment Emergency Reuse System (IWATERS)
- Small scale decontamination

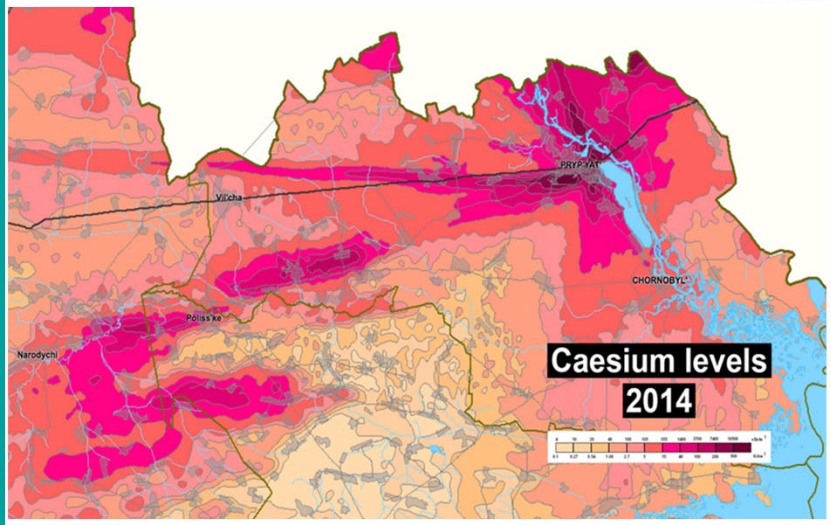


Emergency Phase Events

Atomic Bomb

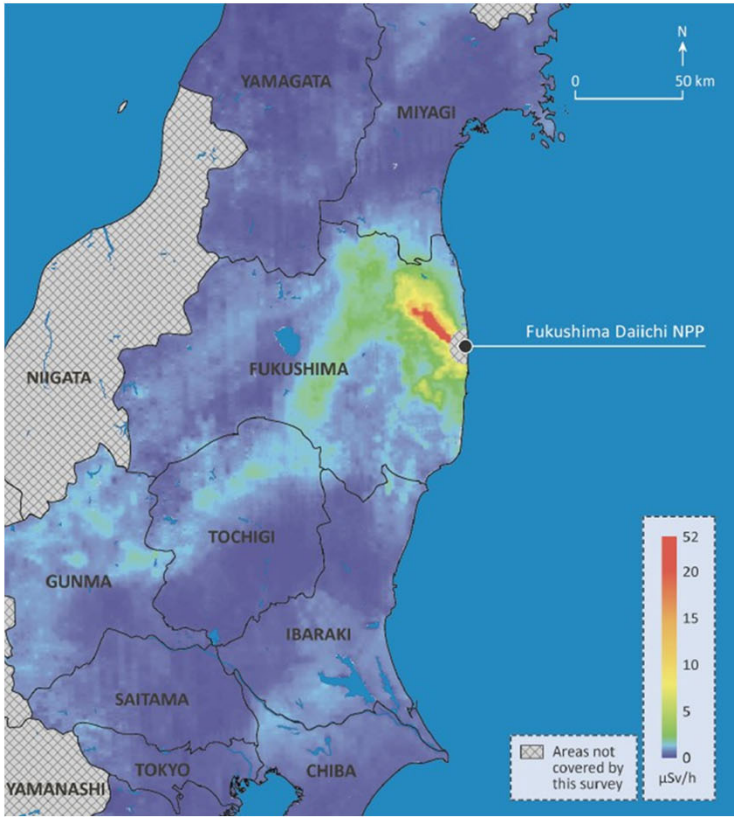


(Simulated) Radiation Dispersal Device (RDD)



(Left)
Radiation resuspension event

(Right)
Nuclear Power Plant Meltdown



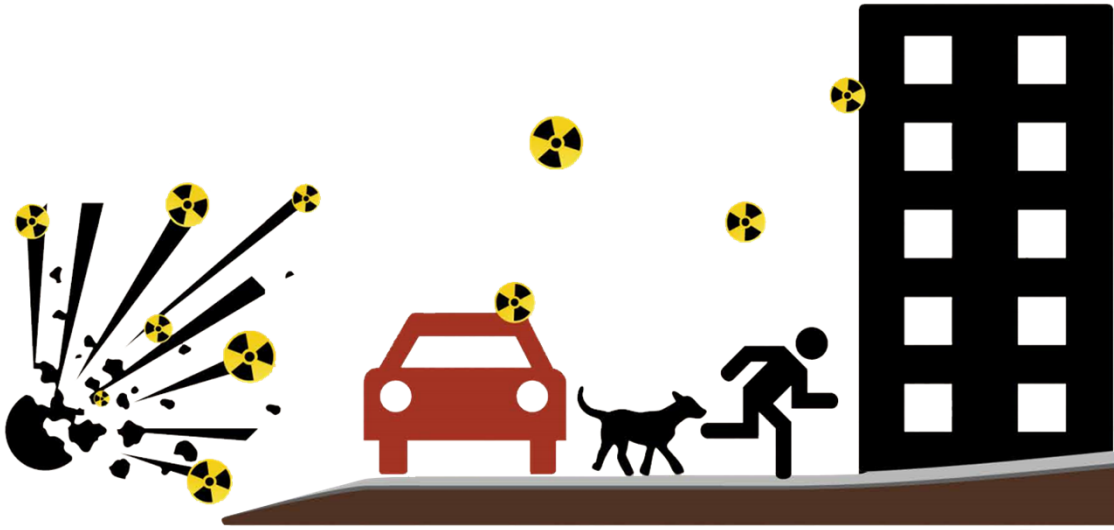
CURRENT RESEARCH

- Current concerns
  - Fukushima
  - Chernobyl
    - After Russian deployment in Ukraine
    - Very few experts exist in this field
    - RDD response

- EPA
  - Currently working under projects for the EPA that will help advise on emergency evacuation and remediation procedures
    - Project for the EPA and National Homeland Security Research Center
- Possible RDD situation
  - An RDD would most likely be deployed in an urban environment
  - Current models use resuspension surface to specifically be soil
- Very few studies exist at all to explain mechanically-induced resuspension

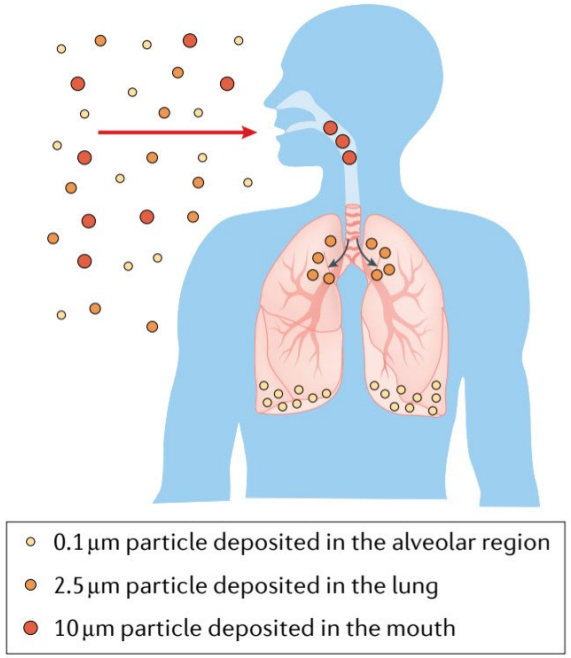
RESUSPENSION

- Emergency phase nuclear events
  - Radiological Dispersal Device (RDD)
  - Improvised Nuclear Device (IND)
  - Nuclear reactor accident
  - Resuspension from closed areas (Chernobyl & Fukushima)
- Evacuations and personnel remediation efforts will be affected by resuspension
- Inhalation of resuspended radioactive particles
  - Radioactive particles can adhere to larger particles that are smaller than 50μm
  - Particles can resuspend and be inhaled



PARTICLE SIZE DEPENDENCE

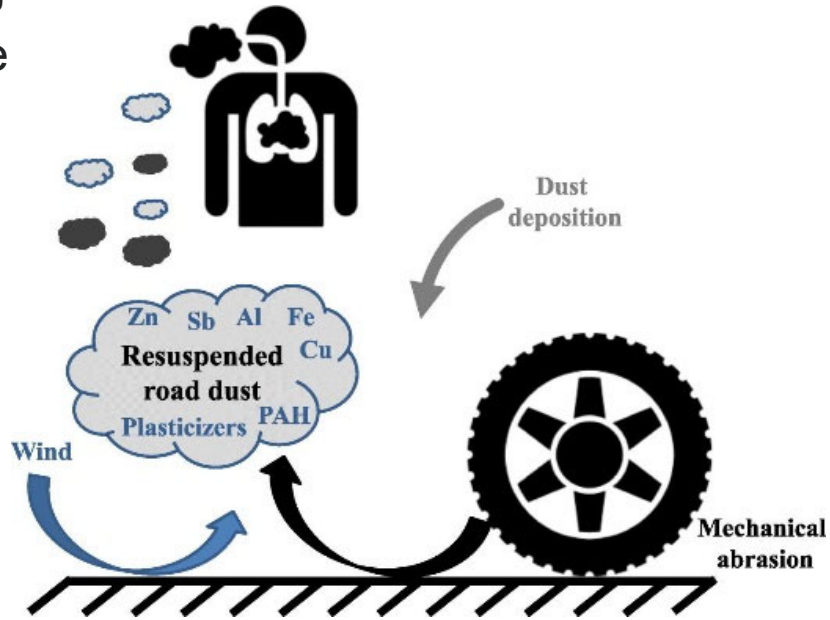
- Respirable particles
  - >50μm particles
    - These particles will not reach respirable height through resuspension
  - 10 - 50μm particles
    - These particles can be caught in the nasal and oral passageways.
  - 3.5 - 10μm particles
    - These are able to be inhaled and do damage to the lungs and be deposited into the tracheal-bronchial tree
    - Including above effects from larger sizes
  - < 3.5μm particles
    - These can deposit into the alveoli and lungs, which could cause major damage to the respiratory system
    - Including above effects from larger sizes



Examples of particle deposition into airways

MECHANICALLY-INDUCED RESUSPENSION

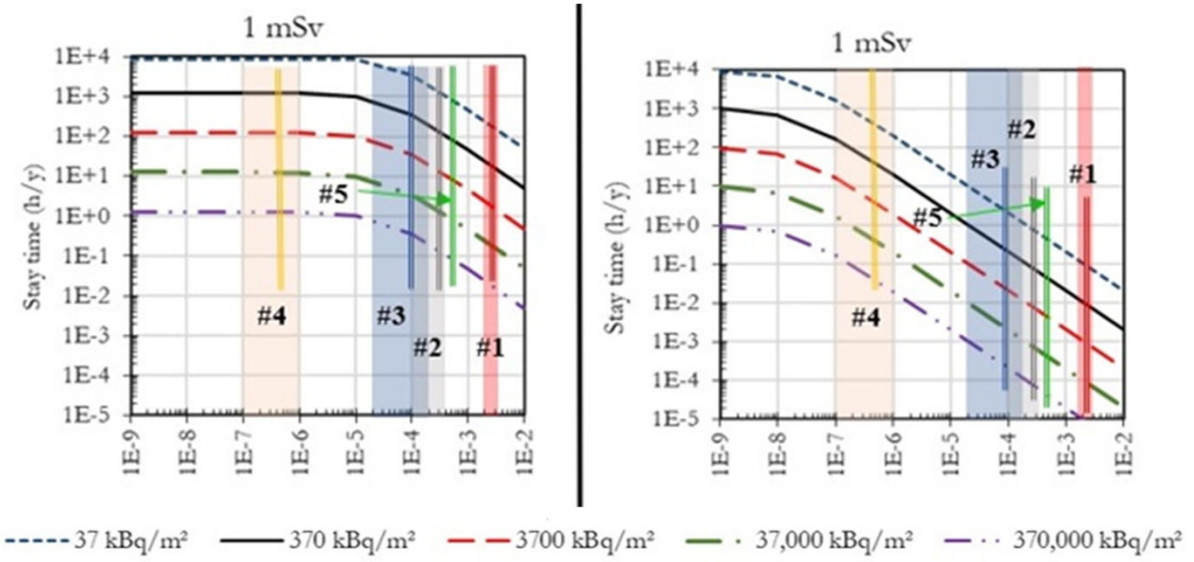
- Refers to a resuspension of particles due to a physical process and not by environmental factors
  - Does not include resuspension due to wind, rain, or other weather-based events
  - Largely dominated in urban areas by vehicle traffic, then pedestrian traffic, saltation, and surface creeping
- Radioactive particles (usually < 3.5μm) will adhere to common roadway materials (1 - 1000μm)
  - These include:
    - abraded tire
    - dislodged pavement
    - recycling pollutant particles
  - These materials can be:
    - Resuspended and inhaled (< 50μm particles)
      - Particles that are 50μm or smaller are not moved when effected solely by wind.
    - Saltation (100-500μm particles)
      - Could resuspend smaller particles
    - Surface Creep (500-1000μm particles)
      - Could resuspend smaller particles



STAY-TIME ANALYSIS

- Graph shows Stay-times in hours vs. Resuspension factors
  - This graph shows the importance of having accurate data for resuspension factor.
  - Having incorrect resuspension factors can lead to drastically different stay times for evacuation and clean up efforts.

- Stay times calculated by RESRAD-RDD for
  - ^{137}Cs (left panel)
  - ^{241}Am (right panel)
    - 1 mSv/yr is the dose limit for the public

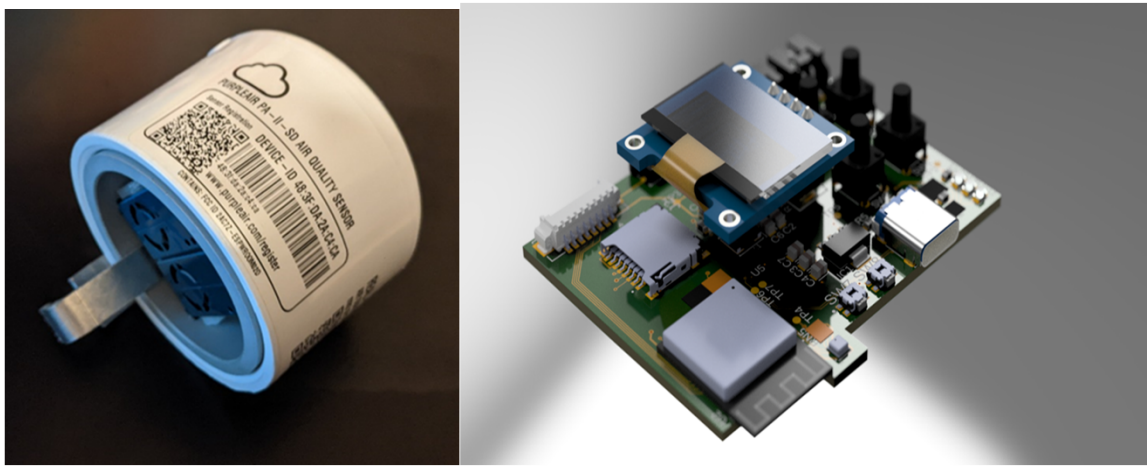


Condition #	Disturbance type	Condition for Use	Recommended Resuspension Factor (m^{-1})	Mean value (m^{-1})
1	Vehicle	Fresh contamination from 0-4 days	$2.7x10^{-3}$-$4.5x10^{-3}$	$3.2x10^{-3}$
2	Vehicle	After many vehicle passes*	$1x10^{-4}$-$4x10^{-4}$	$3.2x10^{-4}$
3	Vehicle	Fresh contamination 4-30 days†	$2x10^{-5}$-$2x10^{-4}$	$9.8x10^{-5}$
4	Vehicle	Fresh contamination >30 days	$1x10^{-7}$-$1x10^{-6}$	$5x10^{-7}$
5	Pedestrian	Fresh contamination (no time limit) with continuous human activity	$5x10^{-4}$	NA

PARTICLE SENSORS

- Particle sensors
  - Display live readouts
  - Quick assessment of data
- Particle sensors used:
  - TSI DustTrak DRX 8533-EP
  - TSI OPS 3330
    - PM 1.0, 2.5, 4.0, 10, >10
    - $10,000-$15,000
    - Flaws:
      - Very expensive
      - Proprietary counting algorithm
  - Purple Air PA-II
    - PM 1.0, 2.5, 10
    - ~$300
    - Flaws:
      - Many
  - Self-made custom particle counter
    - PM 1.0, 2.5, 10
    - ~$100 in components

TSI DustTrak DRX 8533-EP, Field adapted unit.

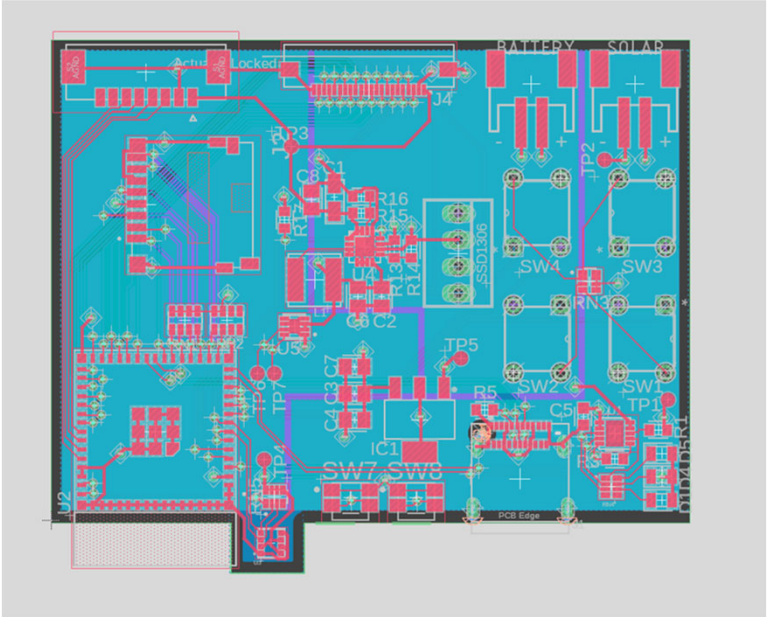


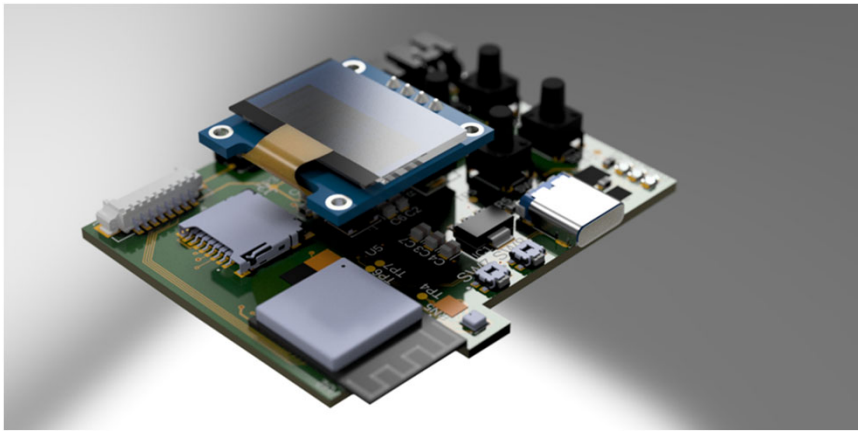
(Left) Purple Air PA-II; (Right) Custom particle counter

CUSTOM PARTICLE COUNTER (CPC)

CPC was used in-lab to test the efficiency with mono sized particles.

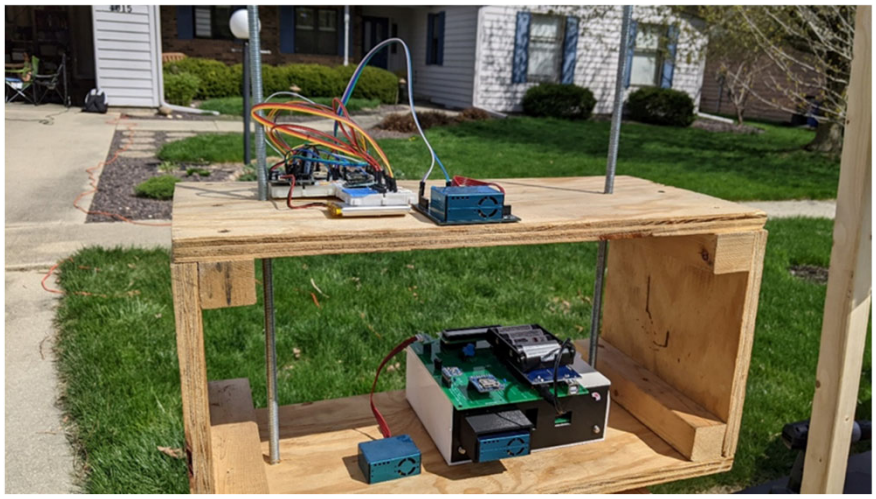
- Components
  - Printed Circuit Board (PCB)
    - All circuitry and board was designed in Fusion 360
  - ESP-32-S3-MINI-1
    - WIFI enabled controller chip
      - Used to store programming that controls all components
      - Programmed in Arduino IDE
  - Plantower PMS5003
    - Particle counts
    - Intake of 0.1L/min
    - PM 1.0, 2.5, 10
    - Measures in $\mu g/m^3$
  - BME 280
    - Temperature, pressure, and humidity
  - Micro SD card reader
  - USB-C connector
    - Charging/Power
  - USB MCP738873 Battery operation manager
    - Allows for charging battery through USB-C or through solar panel port
  - Display and buttons
    - Displays current readings, can be controlled through buttons to start/stop running, connect to WIFI, display battery life, and display temperature, pressure, and humidity.



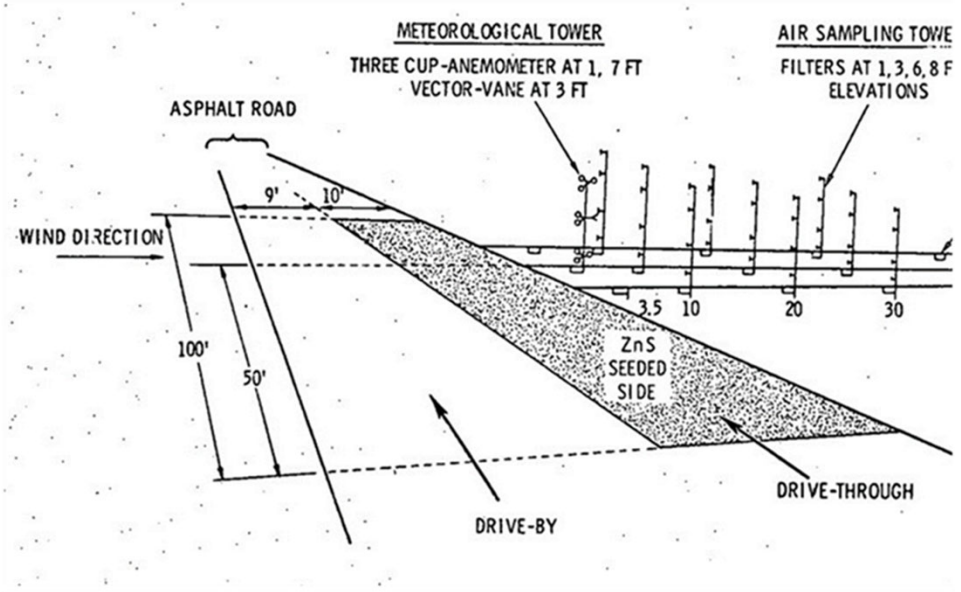


VEHICLE FIELD EXPERIMENTS

- These experiments were the first of their kind in over 30 years
  - since Nicholson in 1989, Sehmel 1973
- The purpose of these studies was to:
  - Evaluate experimental methods and design a template for future experiments
  - Evaluate the DRX and CPC in the field
  - Instructional use for Phys 371 Laboratory at University of Illinois Urbana-Champaign
    - Students were guided with creation of their own simplified custom particle counters
    - Helped with the setup and data acquisition during this field study



FIELD STUDY RESULTS



Trial	*Loading Weight [mg]*	*Surface Area Concentration [mg/m^2]*	*Maximum Air Concentration measured [mg/m^3]*	*Maximum Resuspension factor (S_f)*	*Average Air Concentration measured [mg/m^3]*	*Average Resuspension factor (S_f)*
DRX Seeded road #1	662446	356526	0.016	4.49E-08	0.004	1.12E-08
DRX Seeded road #2	662446	356526	0.038	1.07E-07	0.004	1.12E-08
CPC Seeded road #1	662446	356526	0.020	5.61E-08	0.012	3.37E-08
CPC Seeded road #2	662446	356526	0.020	5.61E-08	0.015	4.21E-08

INVOLVEMENT & ADDITIONAL RESEARCH

- Nuclear Technologies and National Security (NTNS) Diversity, Equity, Inclusion & Accessibility (DEIA) Council Member
- Hispanic/ Latino Club (HLC) Employee Resource Group (ERG) Vice President
- Lab Manager (x2)
- Radioactive Training Exercises
- Inspection Device Research & Exercises
- Tampering Device Research
- Remediation, Evacuation, and Stabilization Research

EMERGENCY PHASE, MECHANICALLY INDUCED, PARTICLE RESUSPENSION AND RESUSPENSION STABILIZATION

UIUC Physics - Careers Seminar

Nico Daiyega PhD

April 4, 2024