

5-24-2021

Evaluation of Potential Exposure Risks from 3D Printing Operations Using NIOSH EVADE Software

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Marcham, C., & Reed, R. (2021). Evaluation of Potential Exposure Risks from 3D Printing Operations Using NIOSH EVADE Software. , (). Retrieved from <https://commons.erau.edu/publication/2035>

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Evaluation of Potential Exposure Risks from 3D Printing Operations Using NIOSH EVADE software

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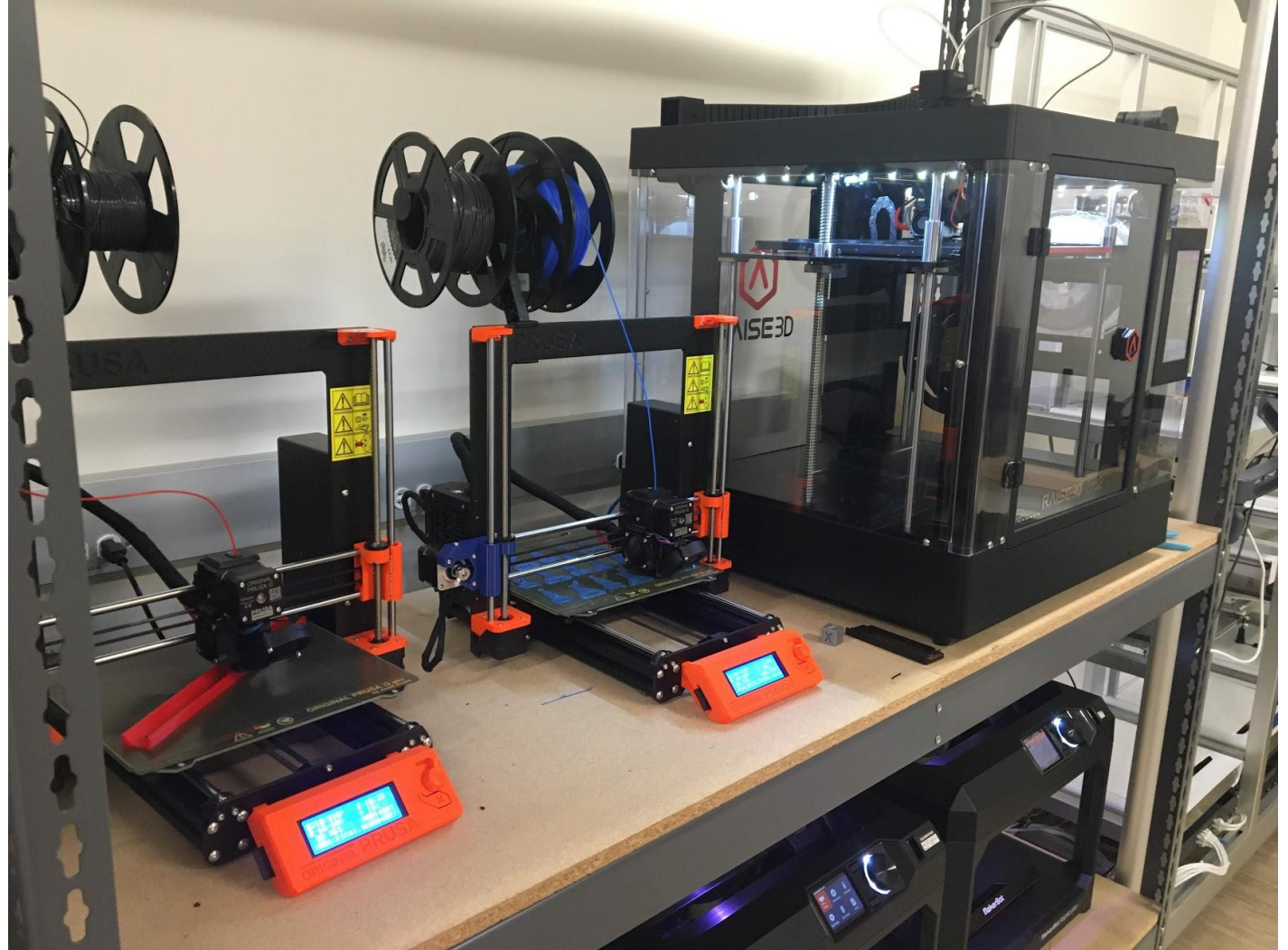
Rustin Reed

- Certified Industrial Hygienist
- Certified Safety Professional
- Doctor of Philosophy
 - Environmental Health Sciences
- Research Interests
 - Mining safety and health
 - Training programs
 - Machine learning
 - Real-time instruments



Overview

- Objectives
- Introduction
- Background
- Methods
- Results
- Conclusion





Research Objectives

1. Address student workers' concern regarding respiratory health
2. Characterize aerosol and VOC exposures during printing operations
3. Identify primary sources of exposure using NIOSH EVADE software, spatial analysis



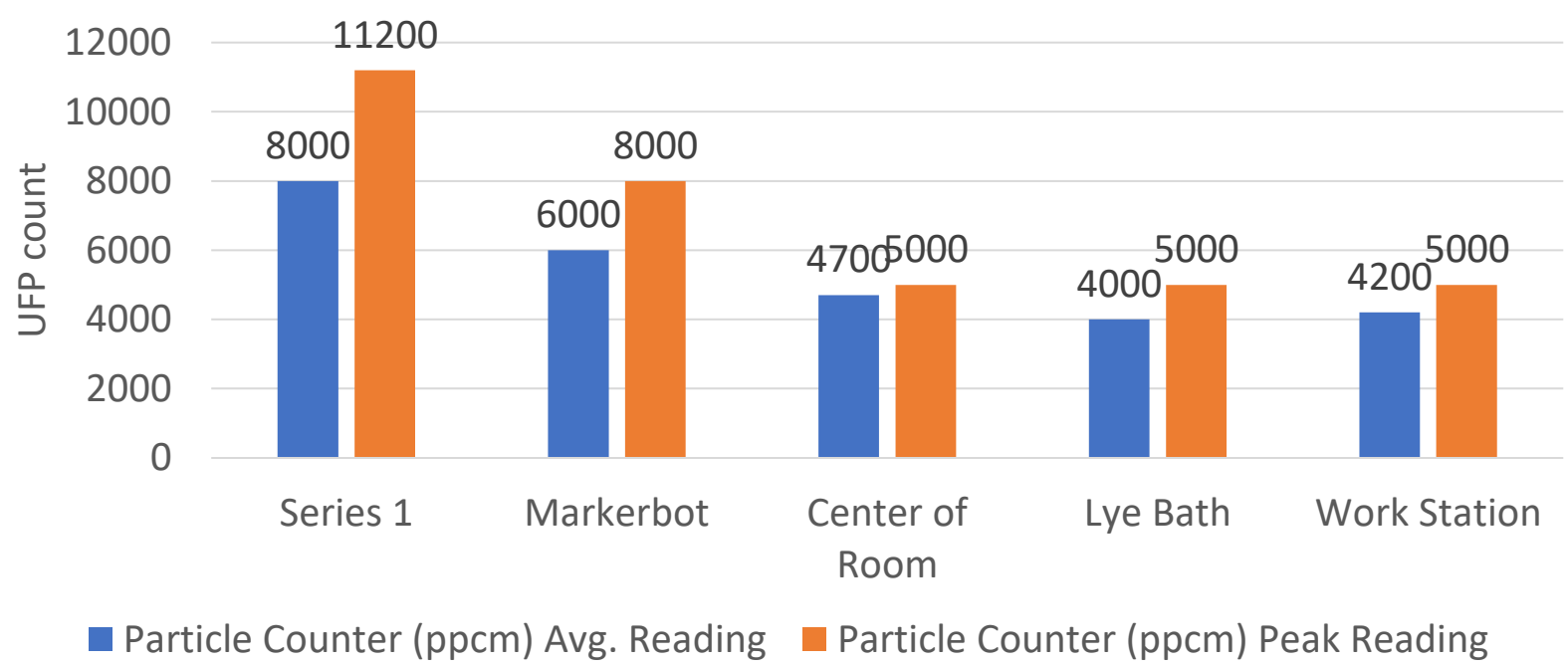
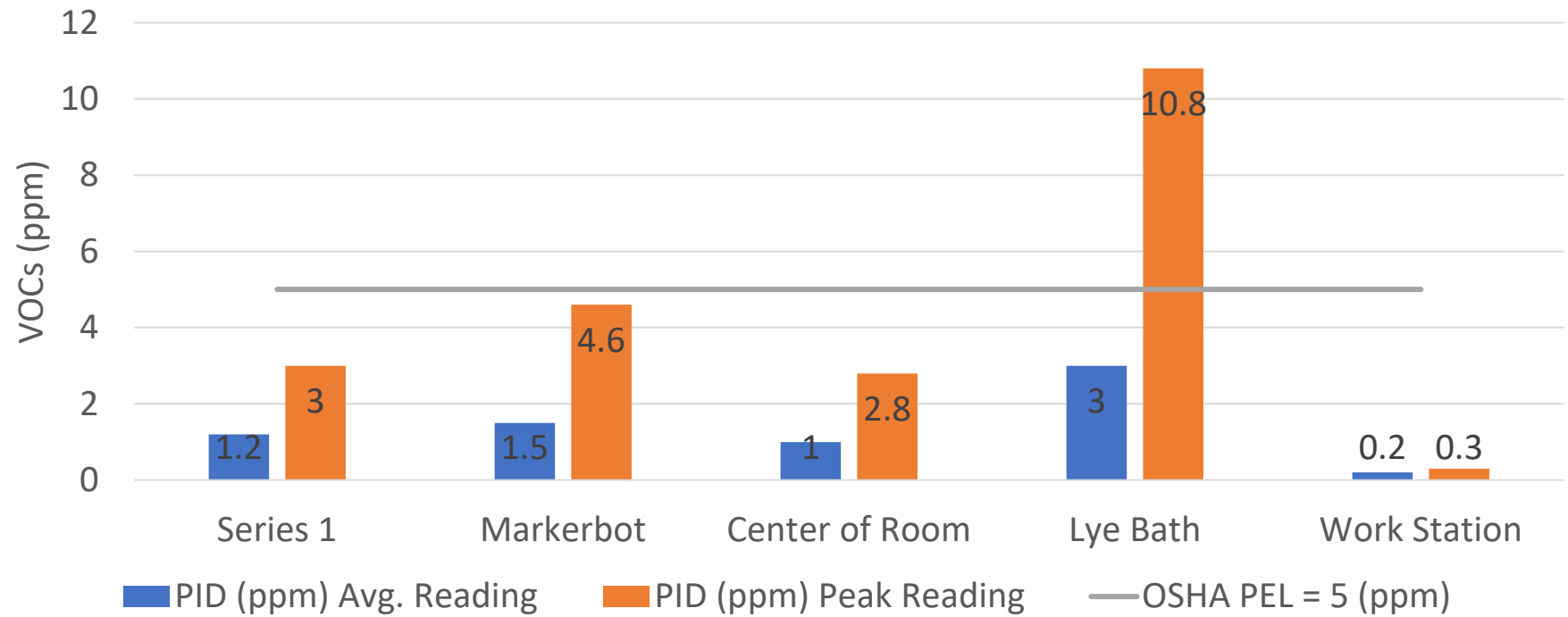
Introduction

- Ultrafine/nanosize particles (UFPs), which are particles less than 100 nm in size
 - (Azimi et al., 2016; Floyd et al., 2017; Kim et al., 2015; Stephens et al., 2013; Stefaniak, LeBouf, Yi et al., 2017; Byrley et al., 2020)
- Volatile organic compounds (VOCs)
 - Styrene
 - Ethylbenzene
 - methyl styrene
 - Acetaldehyde
 - Ethanol
 - Acetone, etc.
 - (Azimi et al., 2016; Floyd et al., 2017; Stefaniak, LeBouf, Yi et al., 2017; Wojtyła et al., 2017; Gu et al., 2019; Byrley et al., 2020).

Background – Old 3D Printing Lab

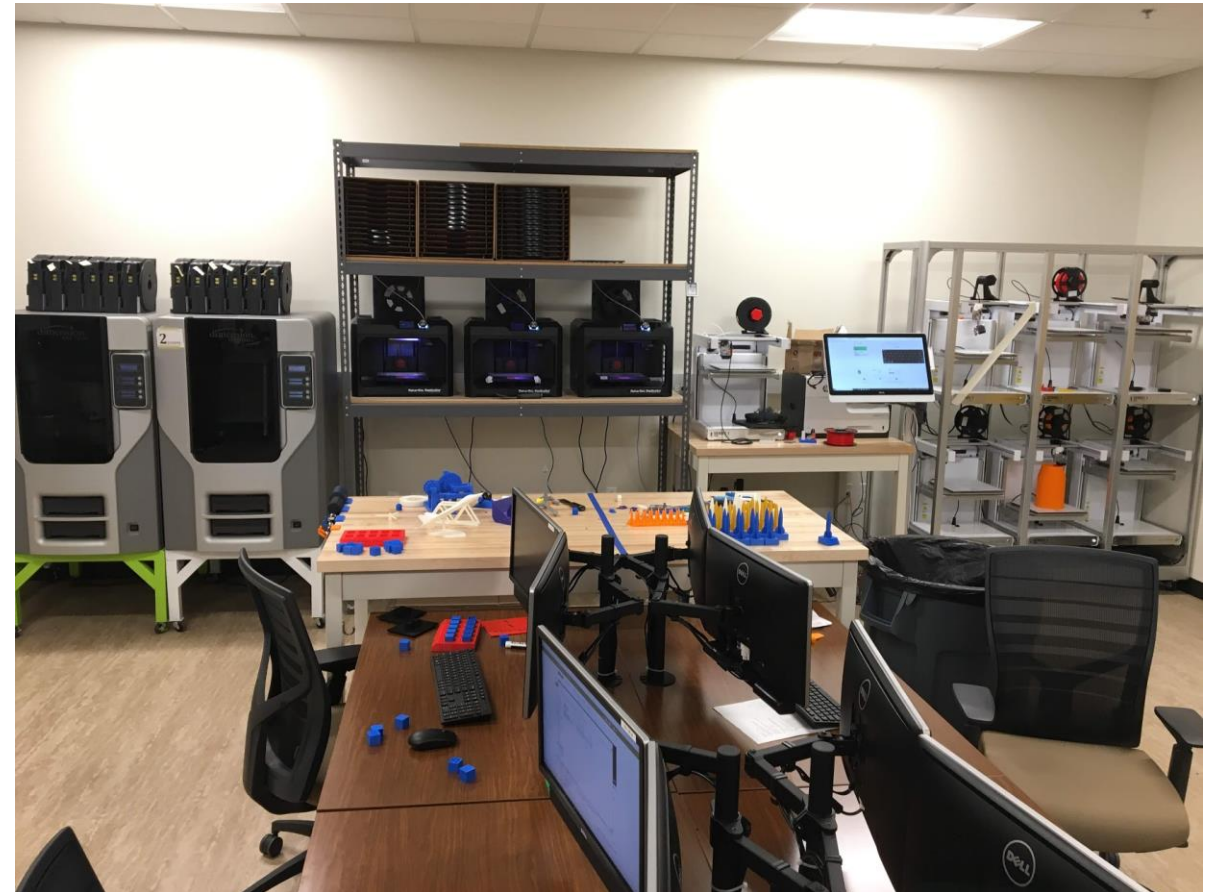
- 1 ABS, 6 PLA printers
- Ion Science Tiger
- TSI P-trak
- Spot measures





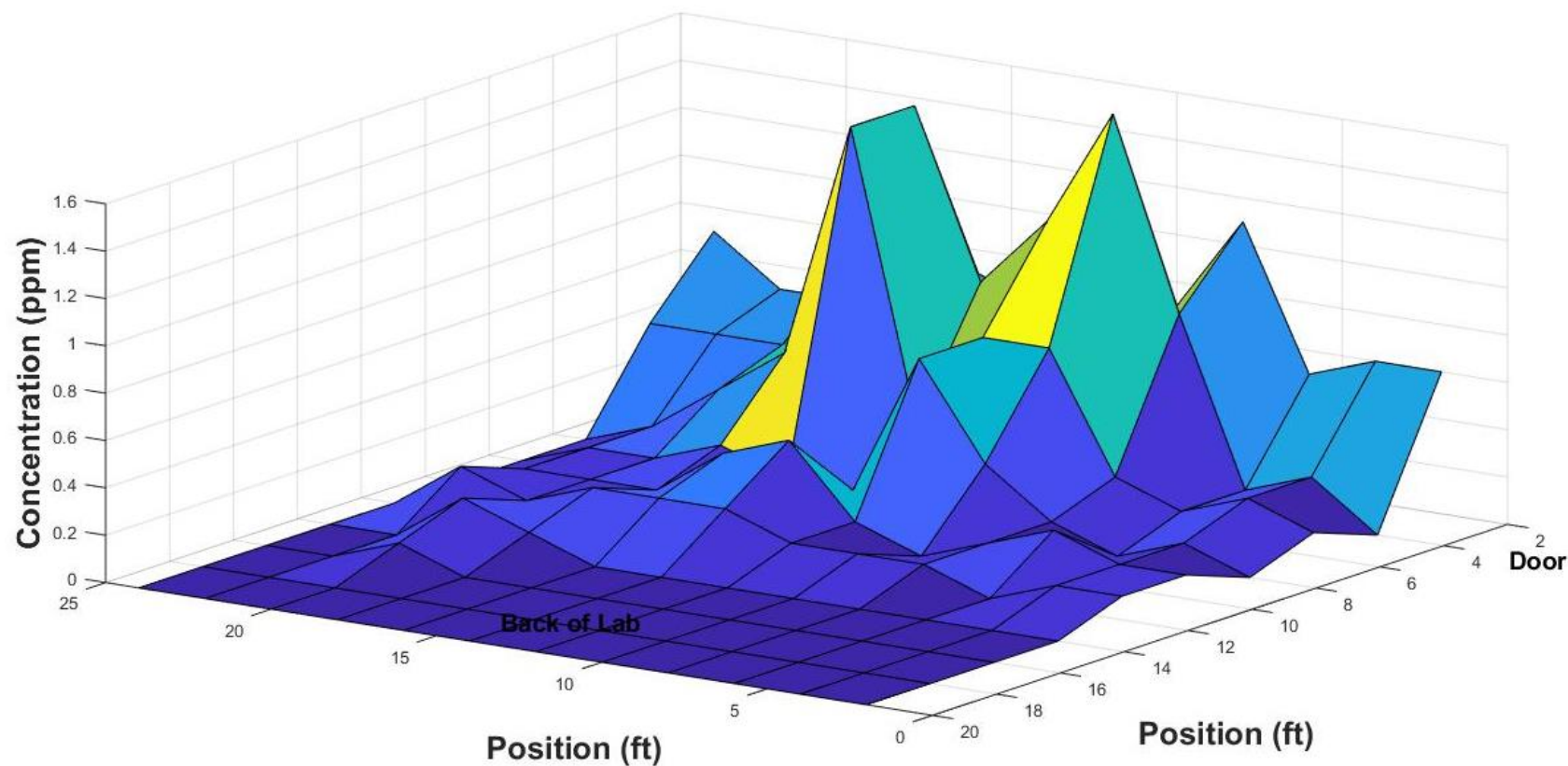
Background – New Rapid Prototyping Lab

- StrataSys F370 (ABS)
- StrataSys F170 (ABS)
- 2x Dimension 1200 ES (ABS)
- 6x MakerBot Replicators (PLA)
- 6x Type A Machines Series 1 Pro (PLA)
- 3x Original Prusa i3 (PLA)
- Form 2 resin printer



Background – Initial VOC measures

- Ion Science Tiger
- Spot measures
- 1 ft x 1 ft grid



Methods - Characterization

- TSI P-Track UFP Monitor
- TSI Sidepak Personal Aerosol Monitor AM520
- Ion Science Tiger LT
- Two 6-L Summa Canisters
- TSI Velocicalc (return air/air changes)



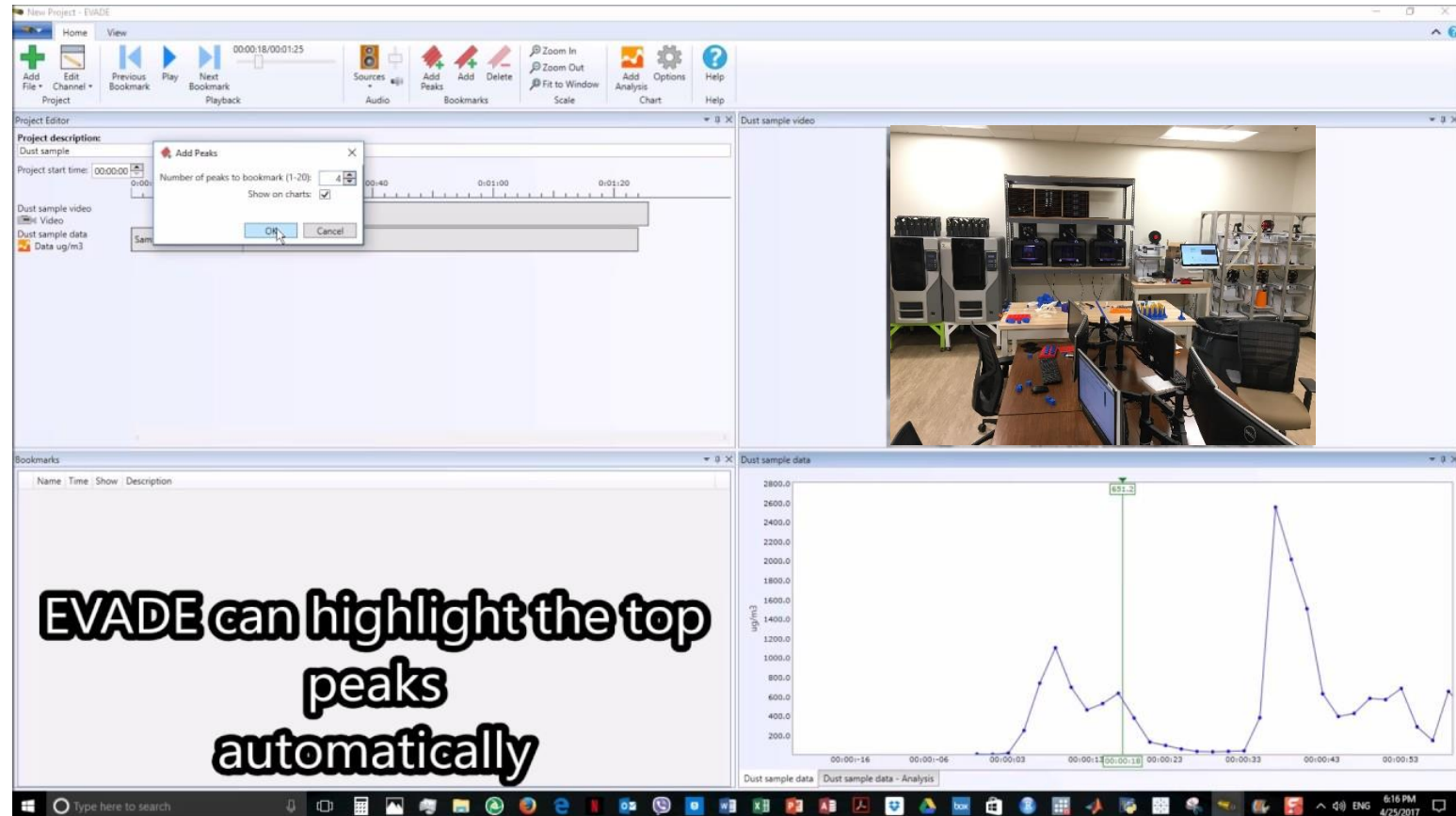
Methods

- Four Particles Plus 7302-AQM Air Quality Monitors
 - 0.3, 0.5, 1.0, 2.5, 5.0, and 10 μm
 - Door, printers, desk, resin printer
- Two Ion Science Cub Personal VOC Detectors
 - Desk, printers
- MIUFLY 1296P HD Police Body Camera



Methods

- NIOSH's EVADE 2.1 software
- Exposure data and video files were imported into EVADE
- Visual task-exposure analysis

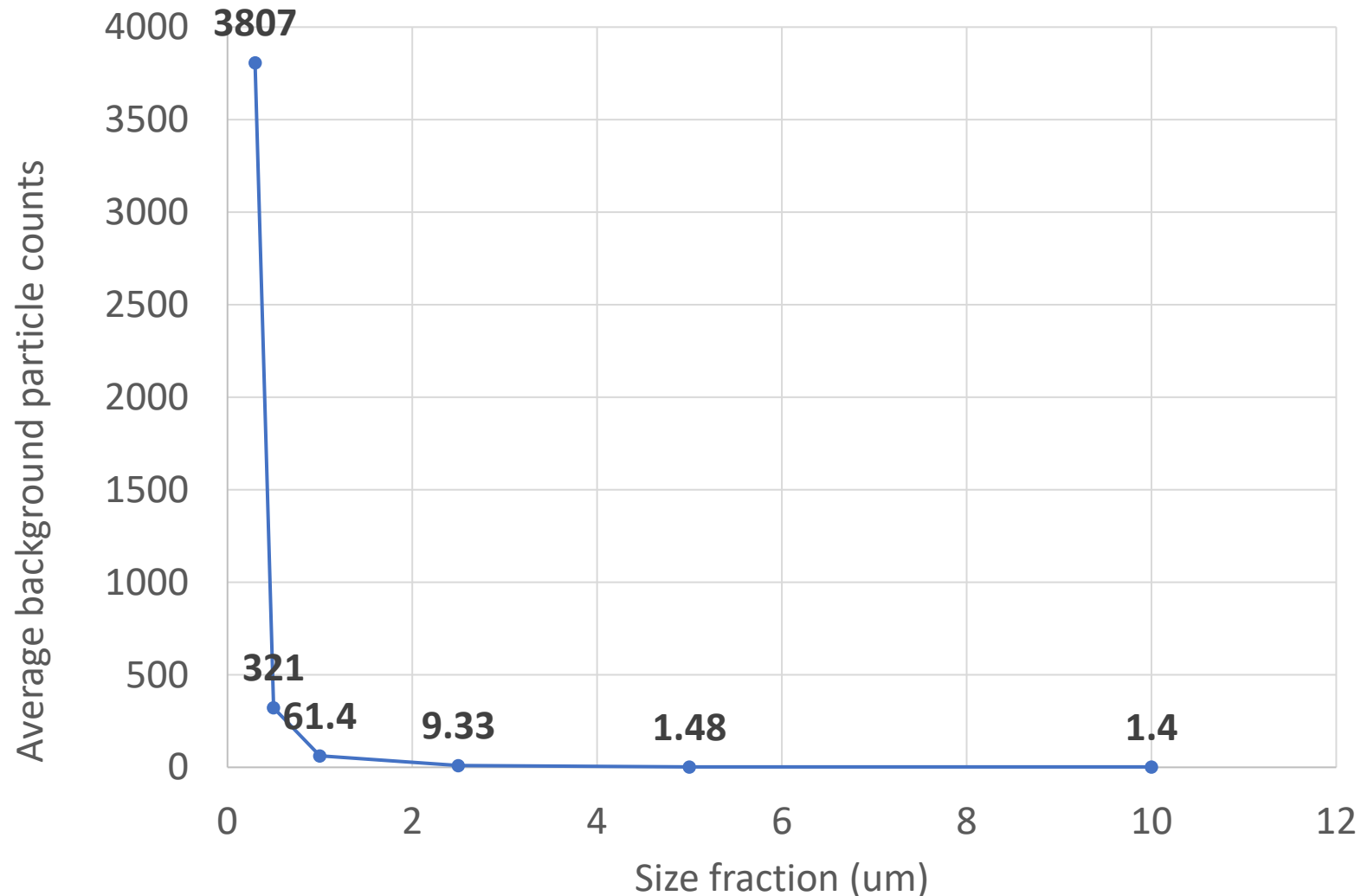


Results – Characterization

- UFP concentrations
 - Average: 2,536 pt/cc
 - Max: 20,998 pt/cc
- 0.1 μm particulate concentrations
 - Average: 4.5 $\mu\text{g}/\text{m}^3$
 - Max: 80 $\mu\text{g}/\text{m}^3$
- The average and maximum VOC concentrations
 - Average: 10 ppb
 - Max: 258 ppb
- Air changes
 - Average: 6.0 per hour
- TO-15 analysis
 - Isopropyl alcohol: 56 ppb
 - Ethanol: 30 ppb
 - Toluene: 6.7 ppb
 - Acetone: 6.5 ppb
 - Acetonitrile: 5.9 ppb

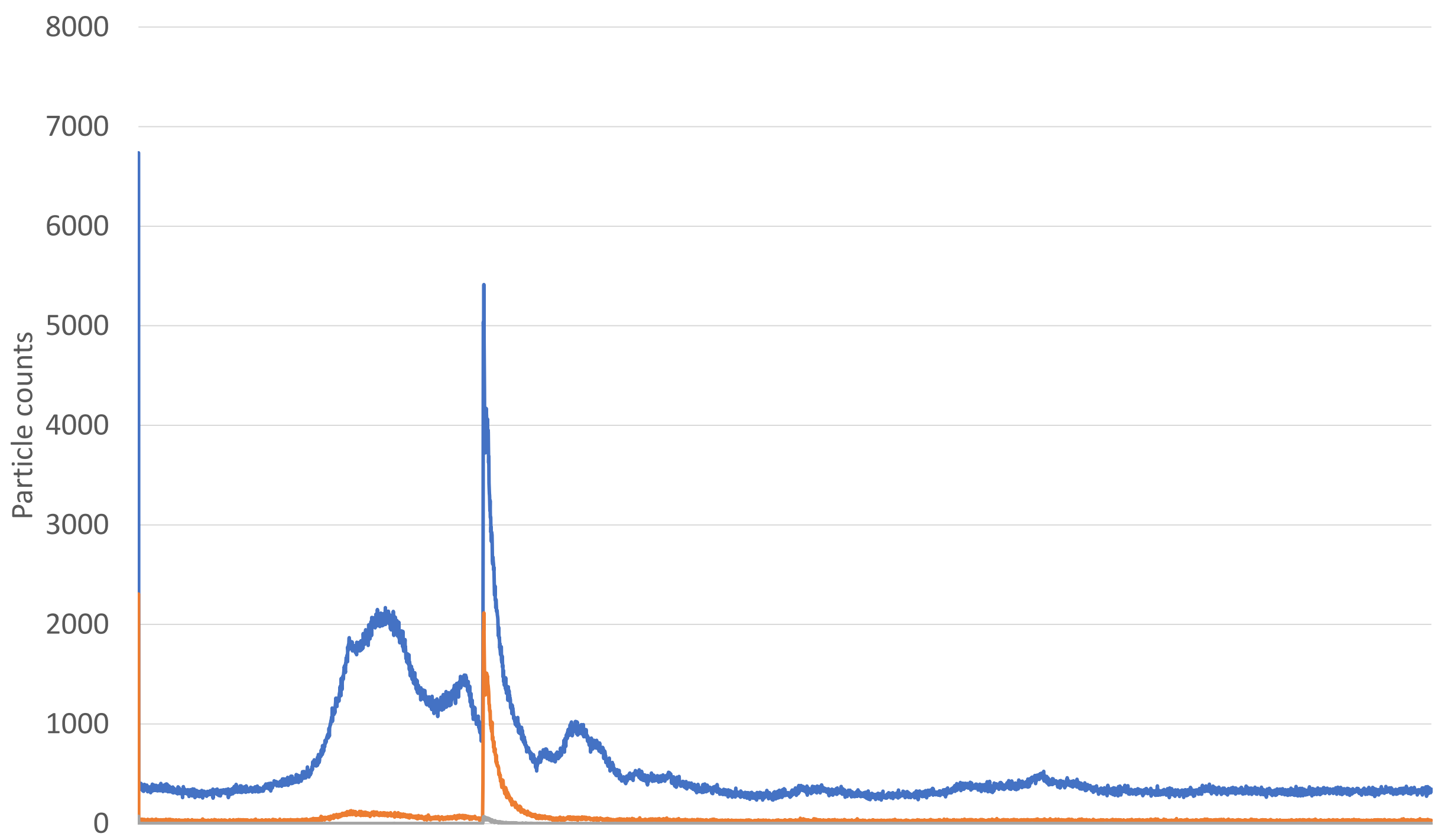
Results – Task-Exposure Analysis

- Average background VOC conc.
- 10 ppb.



Results – Particulates

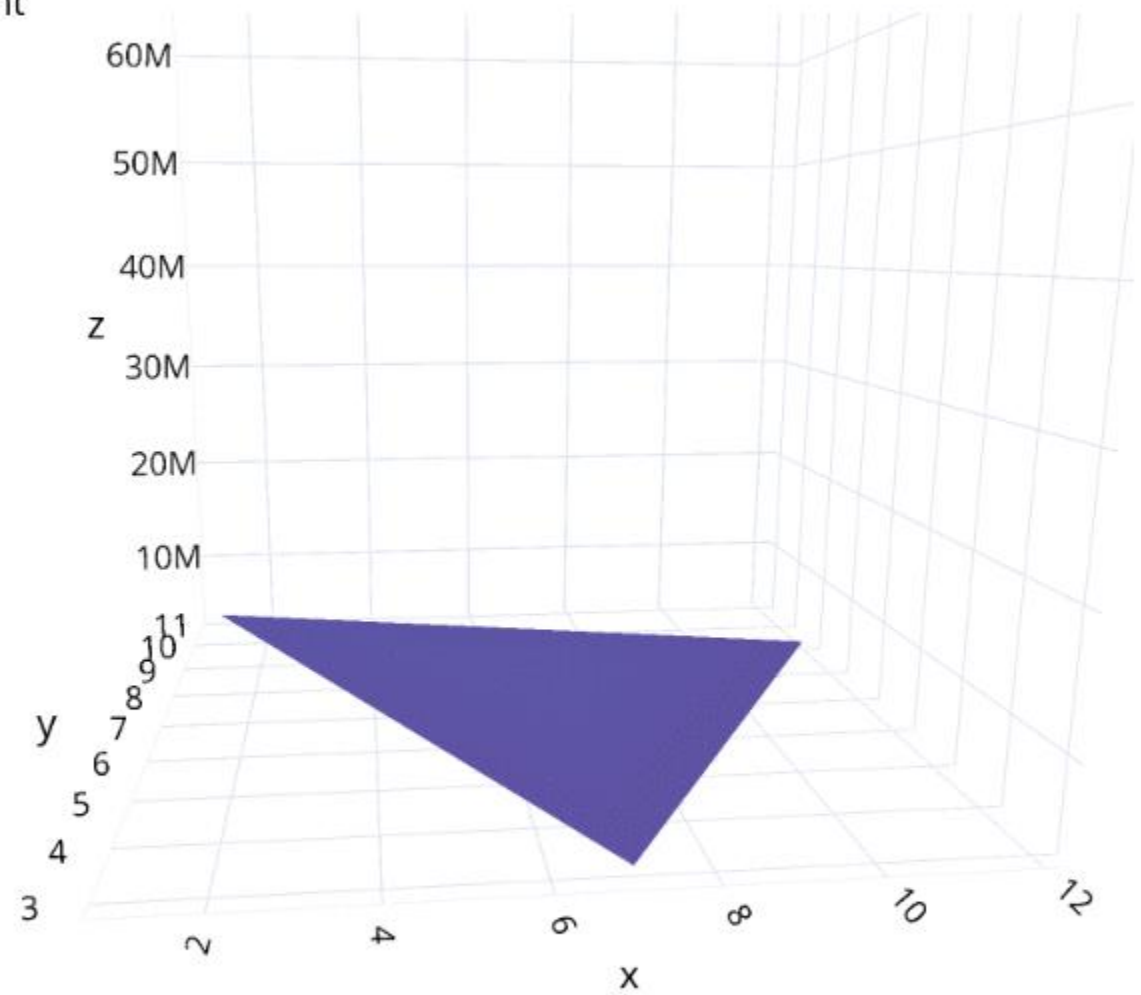
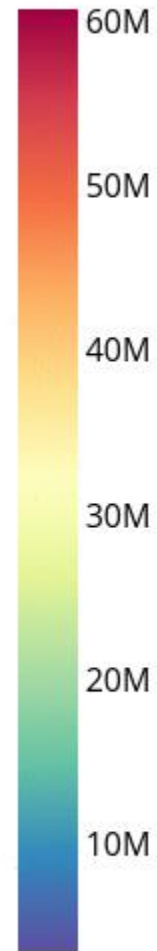
- Washed resin prints in a bath of isopropyl alcohol
 - 0.3 μm aerosol count increased by and peaked at 532%
 - Remained elevated over 130 minutes
 - Cleaned the resin printer build plate, removed resin print supports, and began new prints.
- Applied a primer-filler to a finished PLA print
 - 0.3 μm aerosol counts increased by over 1000%
 - 10 μm aerosol counts increased by nearly 44,000%
 - Returned to background levels within 20 minutes.



Results

- Aerosol can
- Spray near printers
- Door to the left

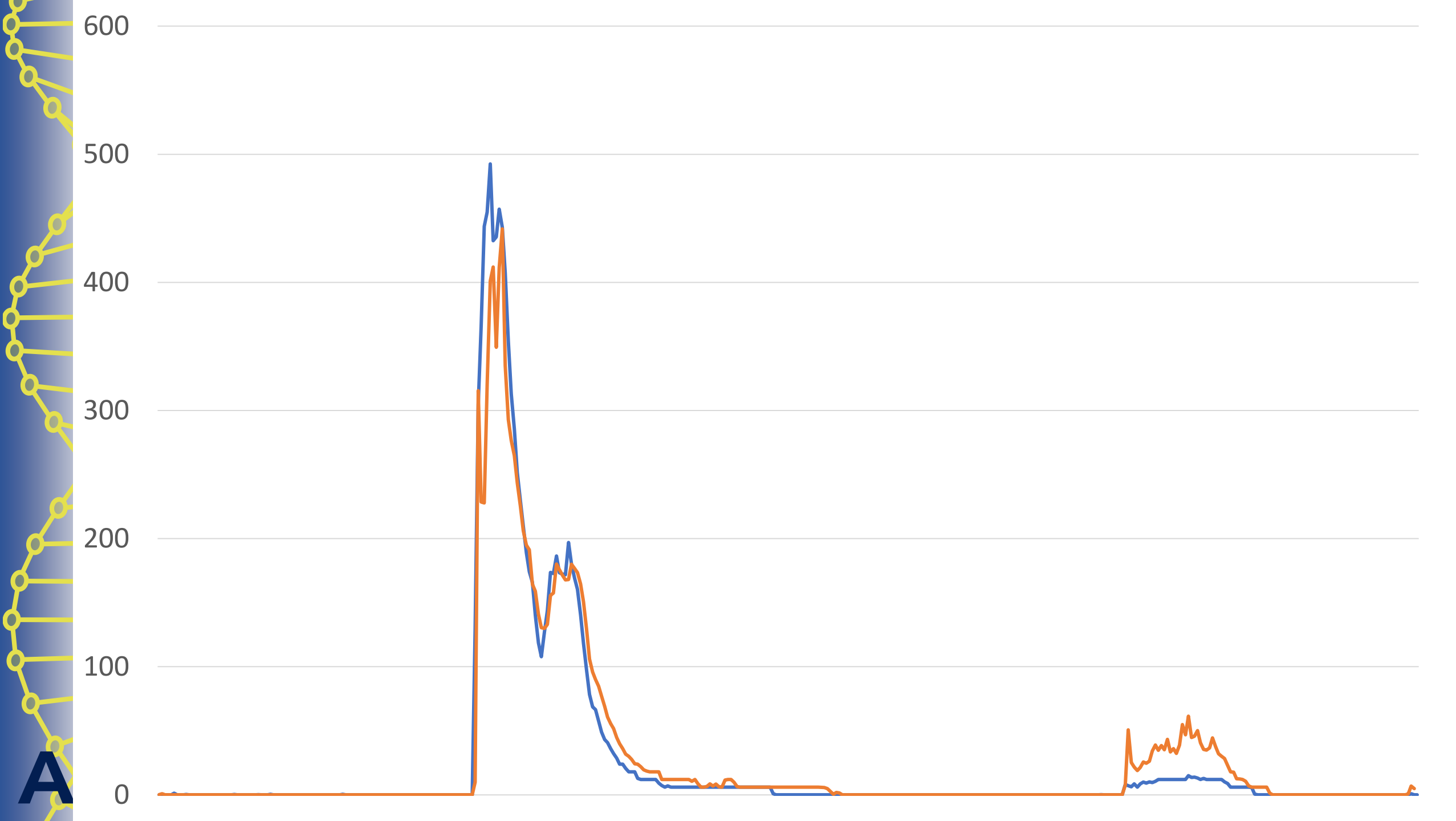
Particle Count





Results – VOCs

- Washed resin prints in a bath of isopropyl alcohol
 - Increased to nearly 500 ppm
 - Steadily fell to background levels within 30 minutes
- Placed an ABS print into a lye (sodium hydroxide) bath
 - Increased to over 60 ppm
 - Remained elevated for approximately 30 minutes.



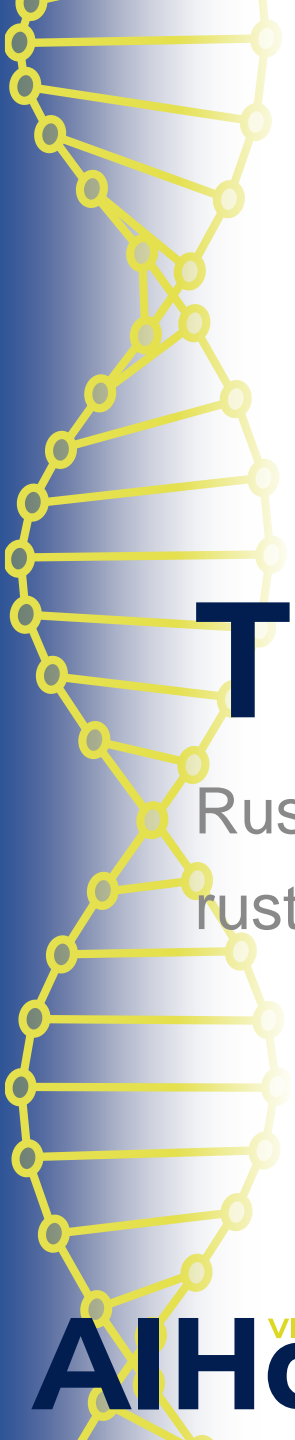
Conclusion – Characterization

- Aerosol and VOC concentrations not strongly correlated
- UFP concentrations relatively low
- Total VOCs during printing processes
 - Around 3-5 ppm consistently
- Primary VOCs identified with the TO-15 canister all were individually detected at 60 ppb or lower

Conclusion – Task-Exposure Analysis

- Keep door open during student work
- Perform post-print processing near door
- Regularly maintain HVAC system
- Printers added – continue to monitor
- Use of video with datalogged exposure information can yield valuable insight





Thank You!

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