Welcome to the Inhalation and Respiratory Specialty Section Webinar

We will begin at: 11:00 AM EDT

Emerging Threats to Indoor Air Quality (IAQ) and Human Health

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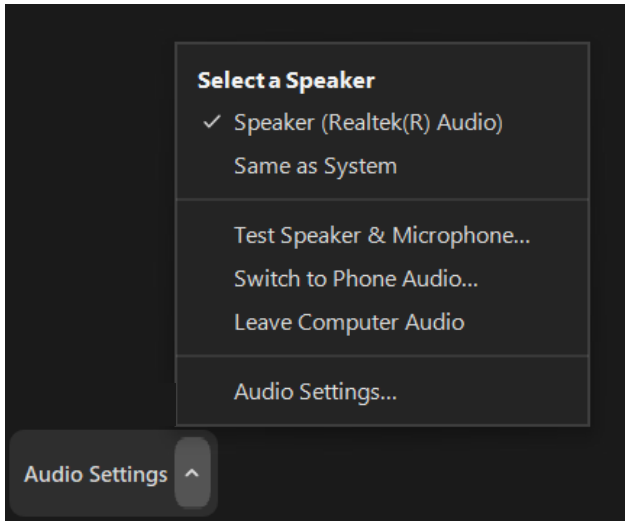

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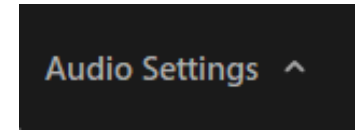
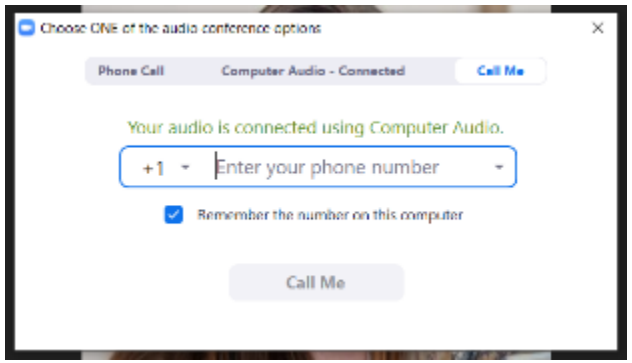
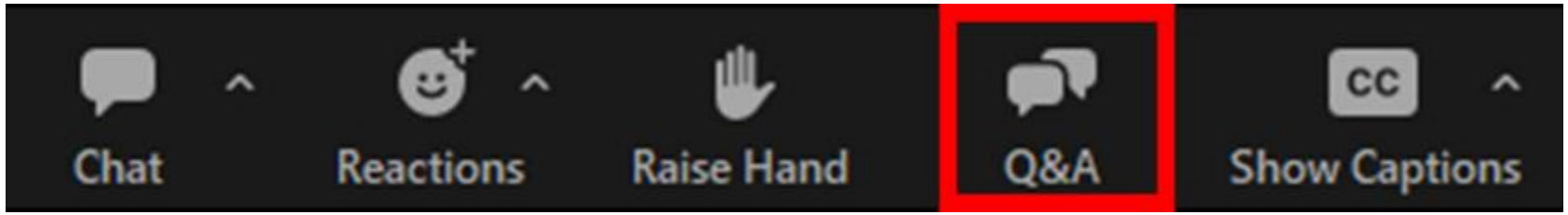




**Please note that this webinar will be recorded.*

Questions…

If you have a question or comment, please use the “Q&A” function on the bottom of your screen.



Inhalation and Respiratory Specialty Section of the Society of Toxicology

Webinar Series 2024-2025

"Emerging Threats to Indoor Air Quality (IAQ) and Human Health"

Presented by ***Chemical Insights Research Institute of UL Research Institutes***

Dr. Cristi Bell-Huff
Research Manager

Dr. Christa Wright
Research Director

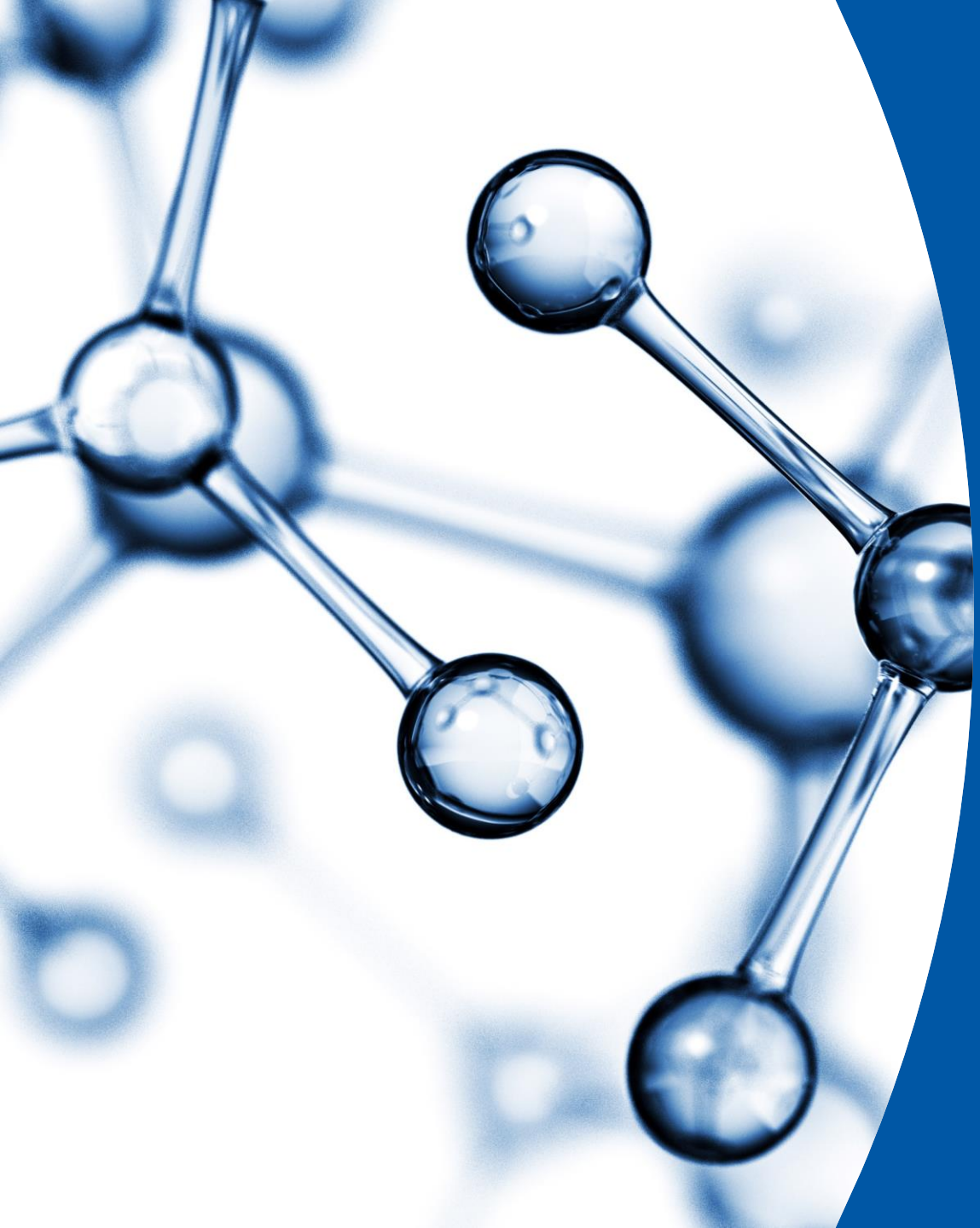
UL Research Institutes | Chemical Insights

Moderators:

- **Todd Stueckle, Ph.D., MA, Associate Service Fellow/Coordinator, CDC/NIOSH**
- **Nikaeta Sadekar, Ph.D., Respiratory Toxicologist, Research Institute for Fragrance Materials**

Session Description

According to the United States Environmental Protection Agency (EPA), most Americans spend 90% of their time indoors. Although outdoor air pollution is thought to be a primary public health concern, short- and long-term exposure to indoor air pollutants may have profound effects on human health and wellbeing. Recent studies have shown indoor air contaminants consisting of biological or chemical pollutants can lead to a variety of health conditions including increased susceptibility to infections, chronic respiratory conditions such as asthma, and lung cancer. Within this webinar, Chemical Insights Research Institute of UL Research Institutes will highlight threats to indoor air quality that stem from the use of various consumer products such as emissions from 3D printers and electronic nicotine delivery systems (ENDS) or e-cigarettes. Additionally, we will describe how extreme heat events propagated by climate change may also jeopardize indoor air quality.



Learning Objectives

1. Discuss parameters that influence indoor air quality such as ventilation, humidity, and temperature
2. Identify chemical and particle emission profiles that are generated while operating 3D printers, during ENDS usage, and from building materials during extreme heat events
3. Discover potential human health implications that might arise due to indoor air pollutant exposure

Agenda

About Chemical Insights Research Institute (CIRI)

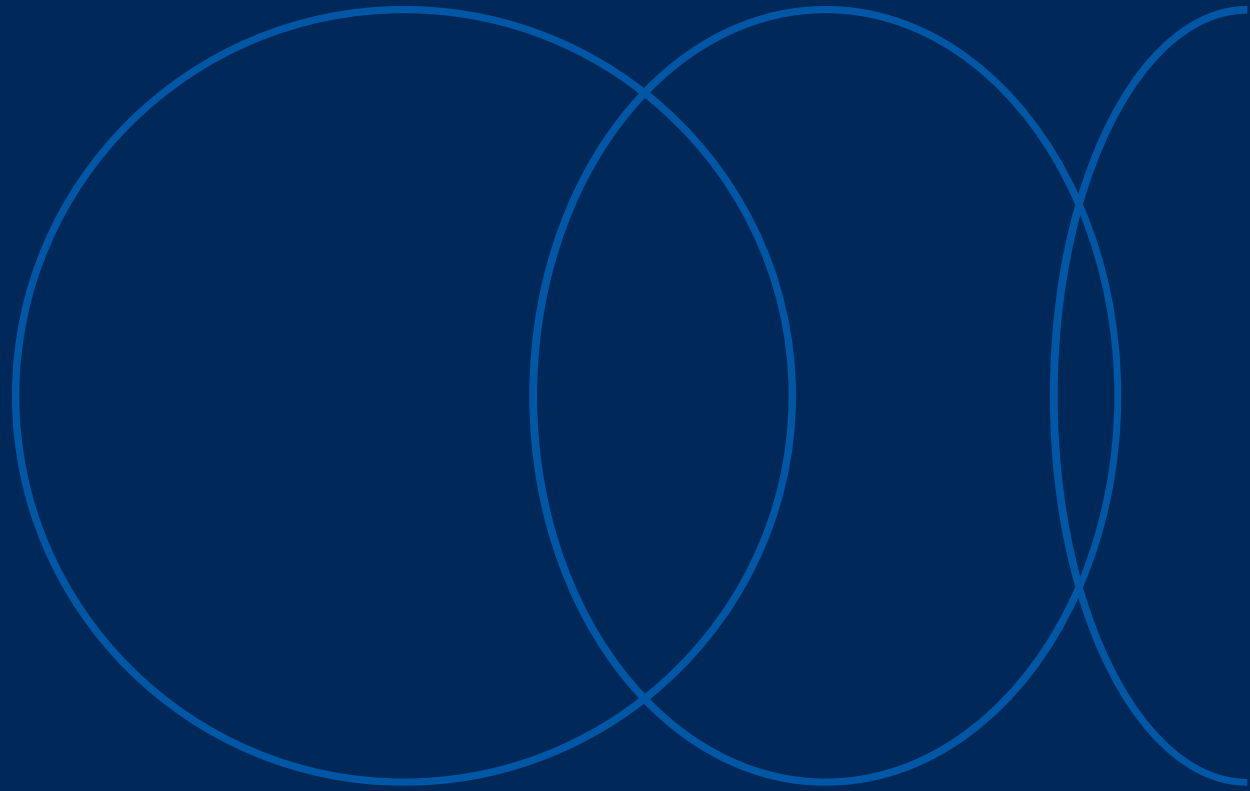
Emerging Threats to IAQ

Impacts on IAQ – Case Studies from CIRI Research

What Can We Do?

Discussion and Q/A

About Chemical Insights Research Institute (CIRI)



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Chemical Insights Research Institute

UL Research Institutes

About CIRI

Chemical Insights Research Institute is dedicated to scientific research, publication, education, and communication on environmental exposures resulting from technologies, and practices, their impact on human health and ways for reducing risks.

Our research efforts contribute to safe working, living, and learning environments for the betterment of societal well-being.

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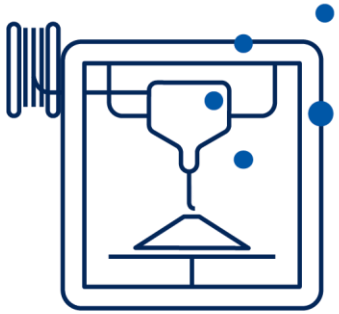
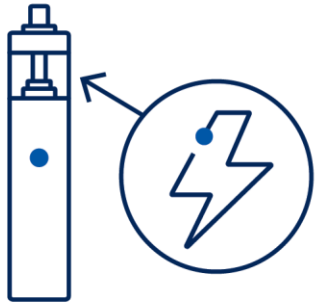
CIRI Research Initiatives



3D Printing Emissions



E-Cigarettes & Vaping

Furniture Flammability

Global Air Pollution

PFAS Exposure

Building Resilience

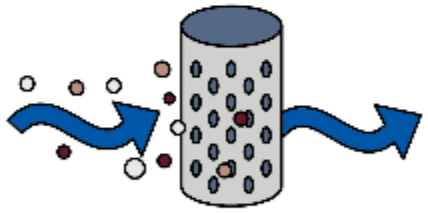
Toxicology

Wildfire Emissions

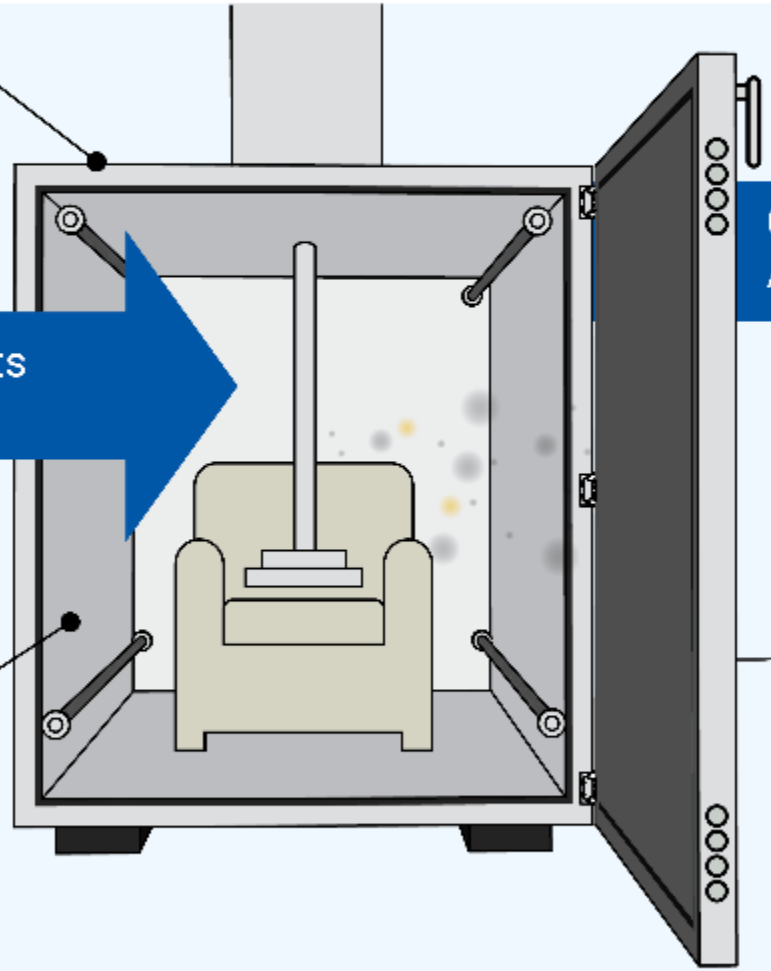
Exposure Chamber Technology

A stainless steel exposure chamber with realistic air flow, temperature and humidity

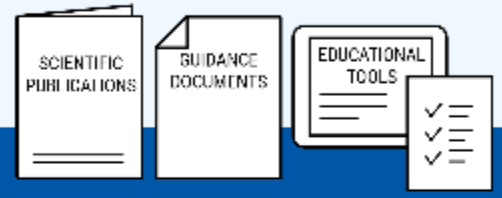
INPUTS: Emerging technologies or products with suspected health hazards

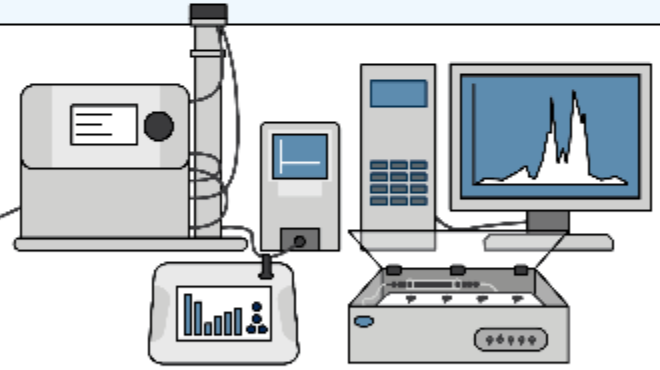


Specialized filtration removes all particles and chemicals from outside air supplied to the chamber to ensure a clean environment.



OUTPUTS: Actionable Data, Safer Use & Application

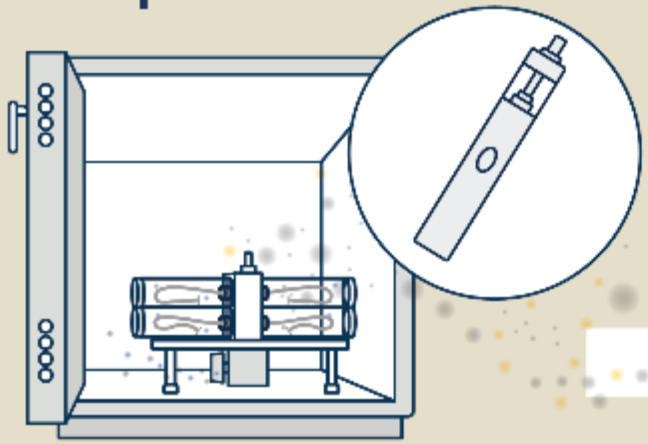




Interface with specialty equipment allows for the collection of data, complex analysis and human exposure modeling.

New Approaches to Assessing Health Impacts

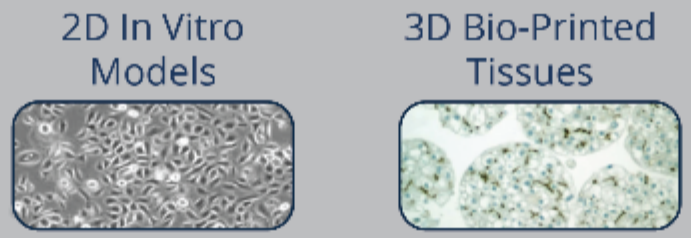
Characterize and Assess "Real World" Exposure Scenarios

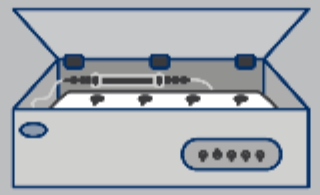


Exposure Chamber

- Determine chemicals or particles of interest in emissions/aerosols
- Develop chemical library for use in high-throughput tox screening

In Vitro Mechanic Assessment





In Vitro Chamber

- Identify pathways of cellular damage, alteration, and disease
- Characterize biomarkers of exposure and injury

Hypothesis-Based Molecular Epidemiology Studies

- Establish causality between biomarkers of exposure and injury
- Create library of biomarkers associated with increased disease risk

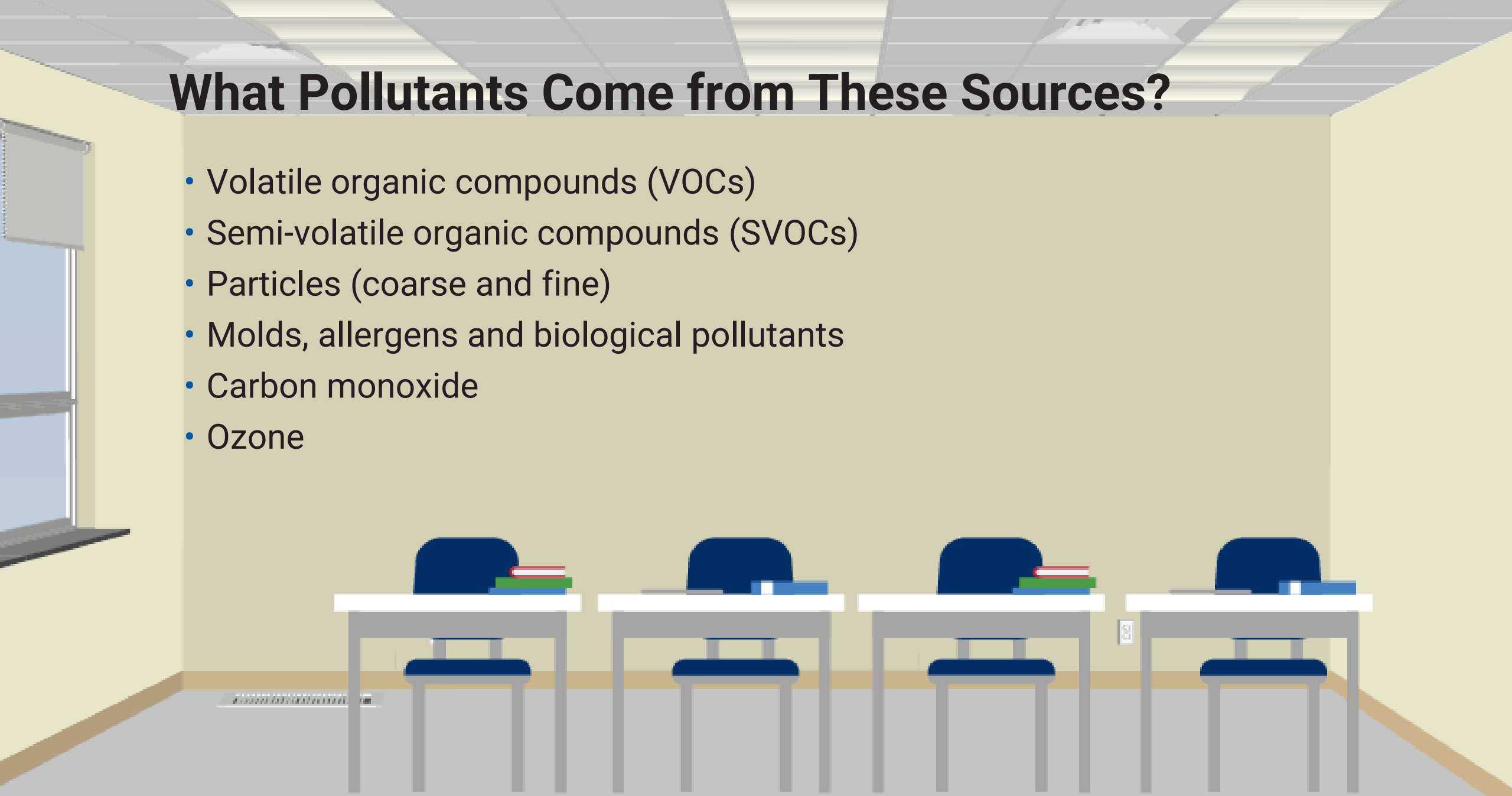
Emerging Threats to IAQ

Where Do Pollutants Come From Indoors?

Sources of Pollutants

What Pollutants Come from These Sources?

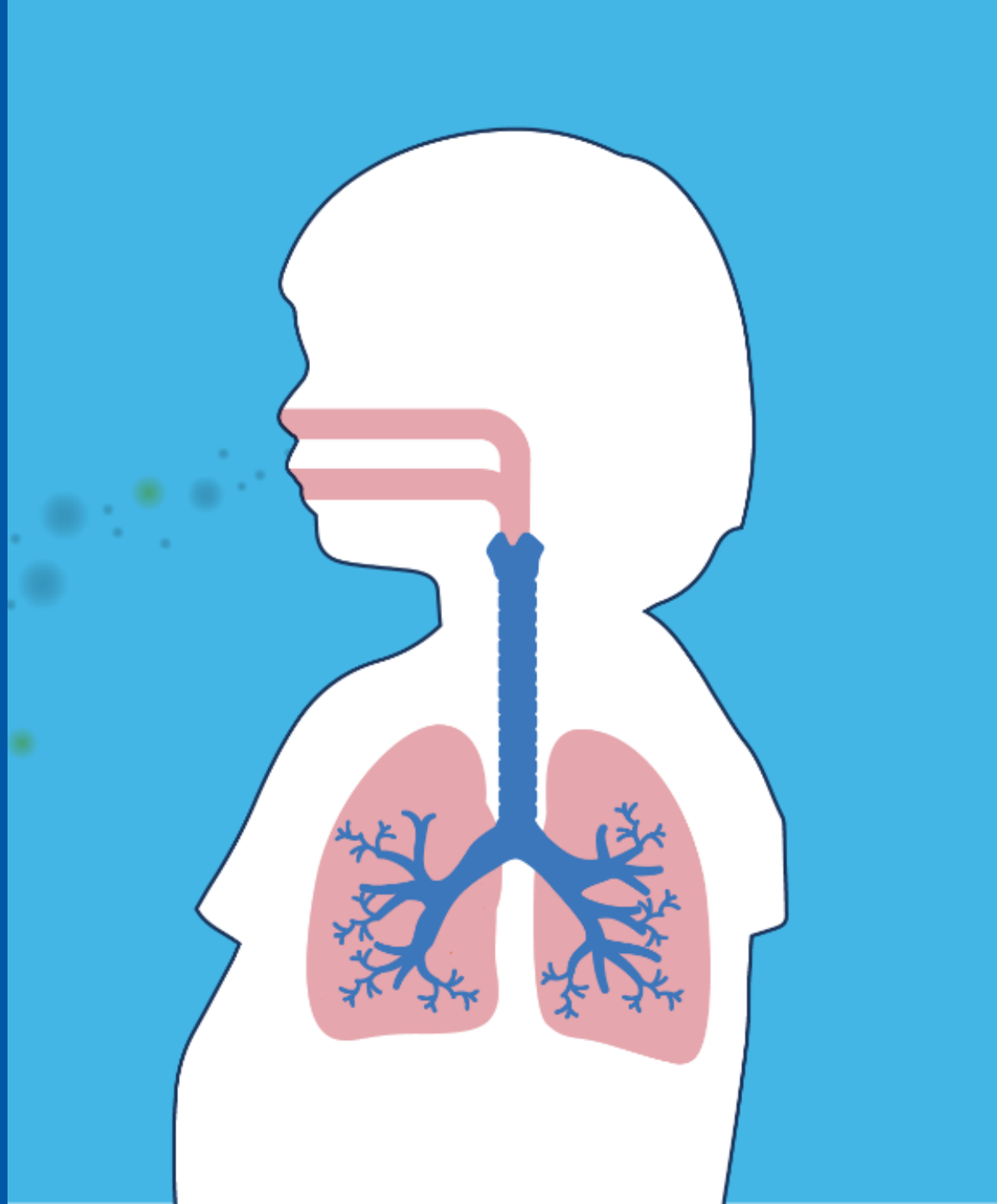
- Volatile organic compounds (VOCs)
- Semi-volatile organic compounds (SVOCs)
- Particles (coarse and fine)
- Molds, allergens and biological pollutants
- Carbon monoxide
- Ozone



Source: Reference Guide for Indoor Air Quality in Schools: Typical Sources of Indoor Air Pollutants
U.S. Environmental Protection Association

KNOWN HEALTH IMPACTS

- Irritation of the eyes, nose, and throat
- Headaches, dizziness, and fatigue
- Respiratory diseases (e.g. asthma, COVID-19)
- Heart disease
- Cancer



Sensitive Populations




Health Consequences: Children

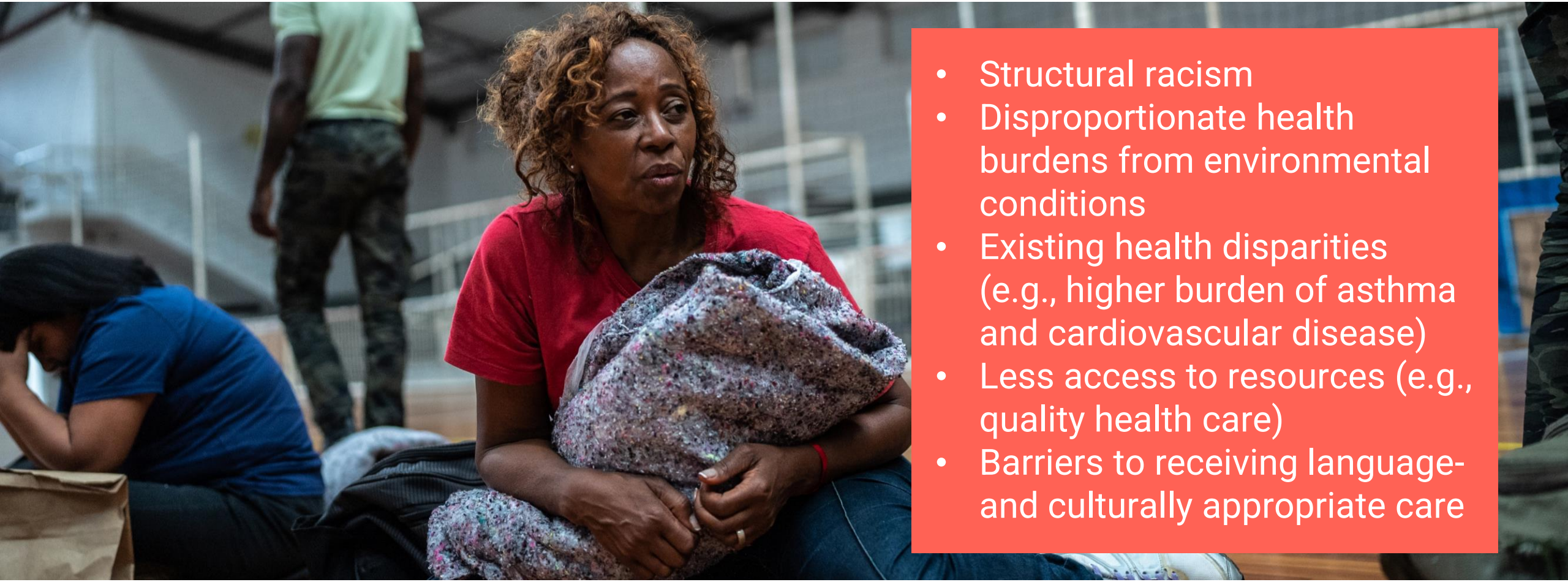
All children are considered sensitive to air pollution.

Children:

- Engage in more vigorous activity
- Inhale more air per pound of body weight
- Have developing organs and immature immune response

Source: Which Populations Experience Greater Risks of Adverse Health Effects Resulting from Wildfire Smoke Exposure? U.S. Environmental Protection Association

Health Consequences: Disadvantaged Populations



- Structural racism
- Disproportionate health burdens from environmental conditions
- Existing health disparities (e.g., higher burden of asthma and cardiovascular disease)
- Less access to resources (e.g., quality health care)
- Barriers to receiving language- and culturally appropriate care

Source: Which Populations Experience Greater Risks of Adverse Health Effects Resulting from Wildfire Smoke Exposure? U.S. Environmental Protection Association

EMERGING RISKS CONTRIBUTING TO POOR IAQ

3D printers (New/emerging technologies)

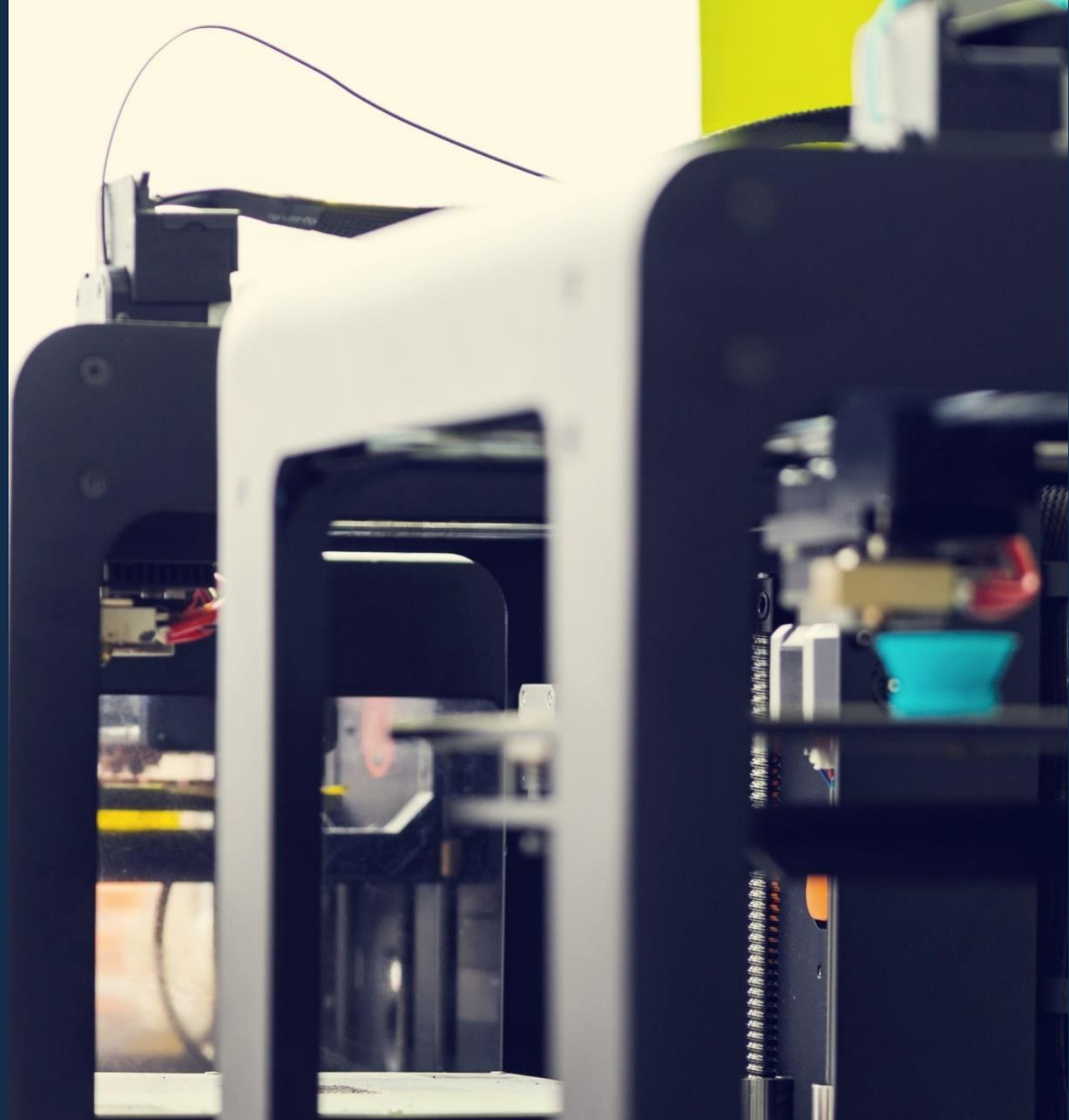
Emissions generated by ENDS (Vaping)

Increased pollutant exposure from climate & weather

Cleaning to mitigate aerosol transmission

Emerging Risk:

3D Printers



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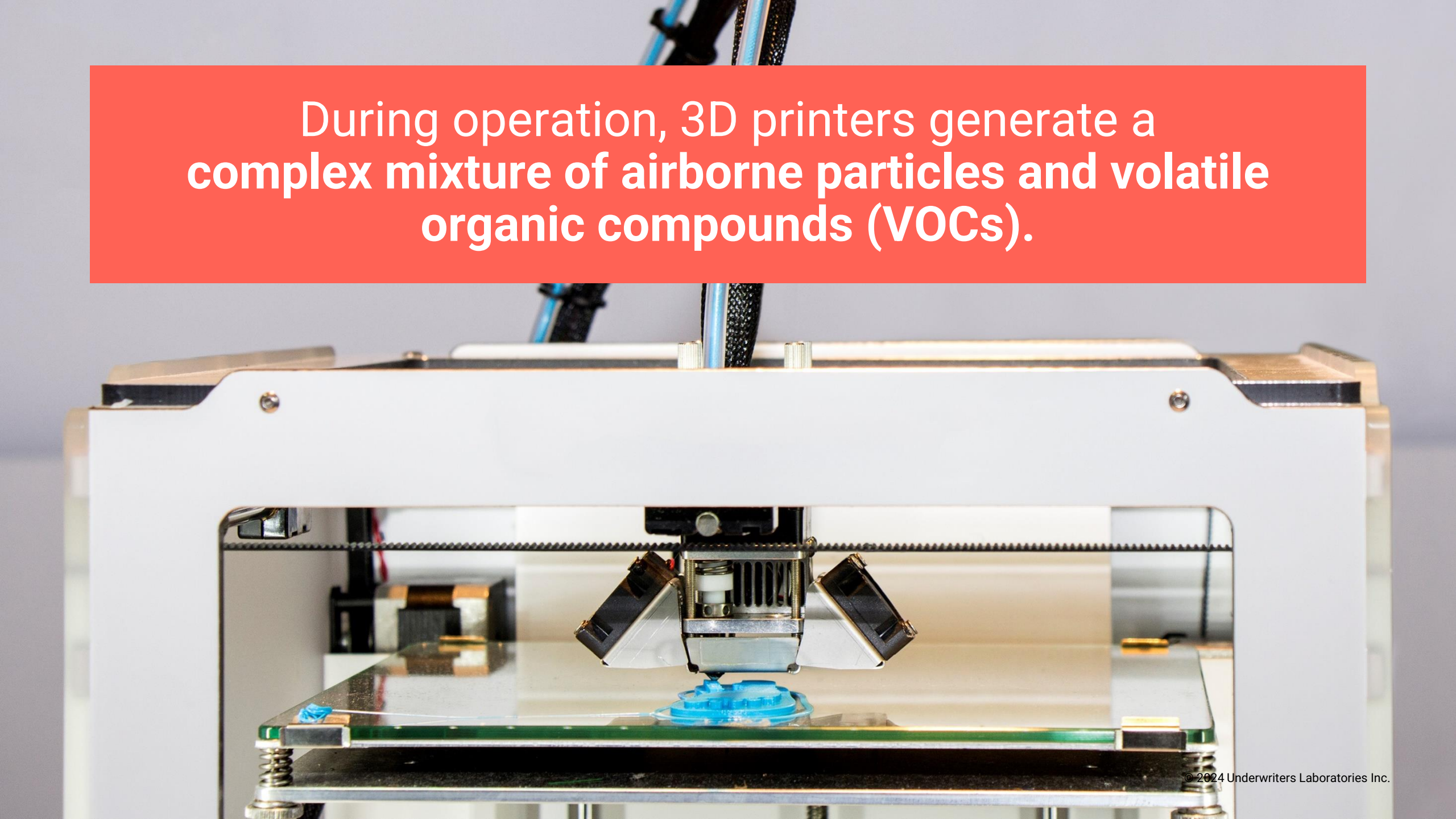
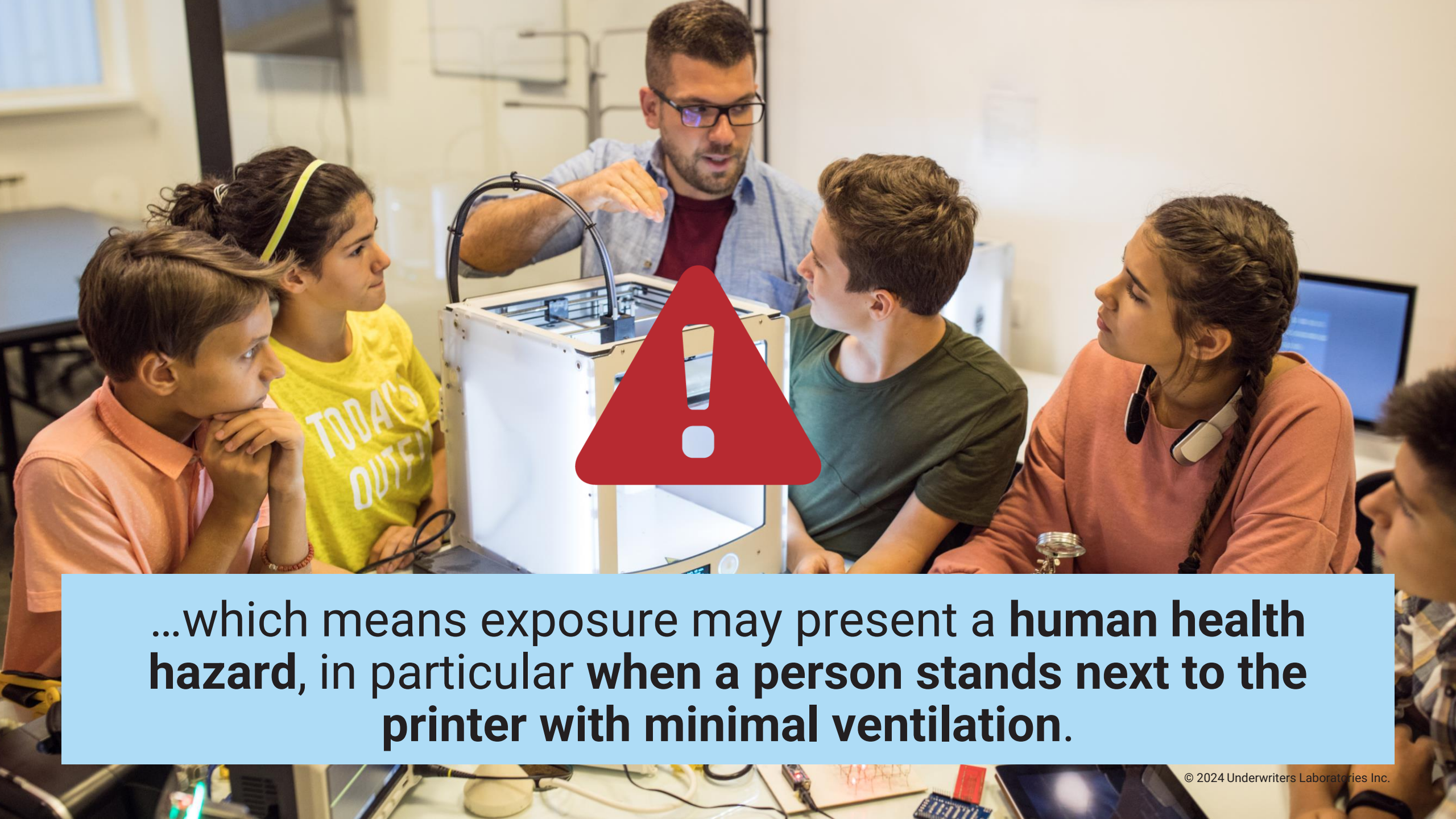


During operation, 3D printers generate a **complex mixture of airborne particles and volatile organic compounds (VOCs).**



…which means exposure may present a **human health hazard**, in particular **when a person stands next to the printer with minimal ventilation**.

Emerging Risk:

Vaping

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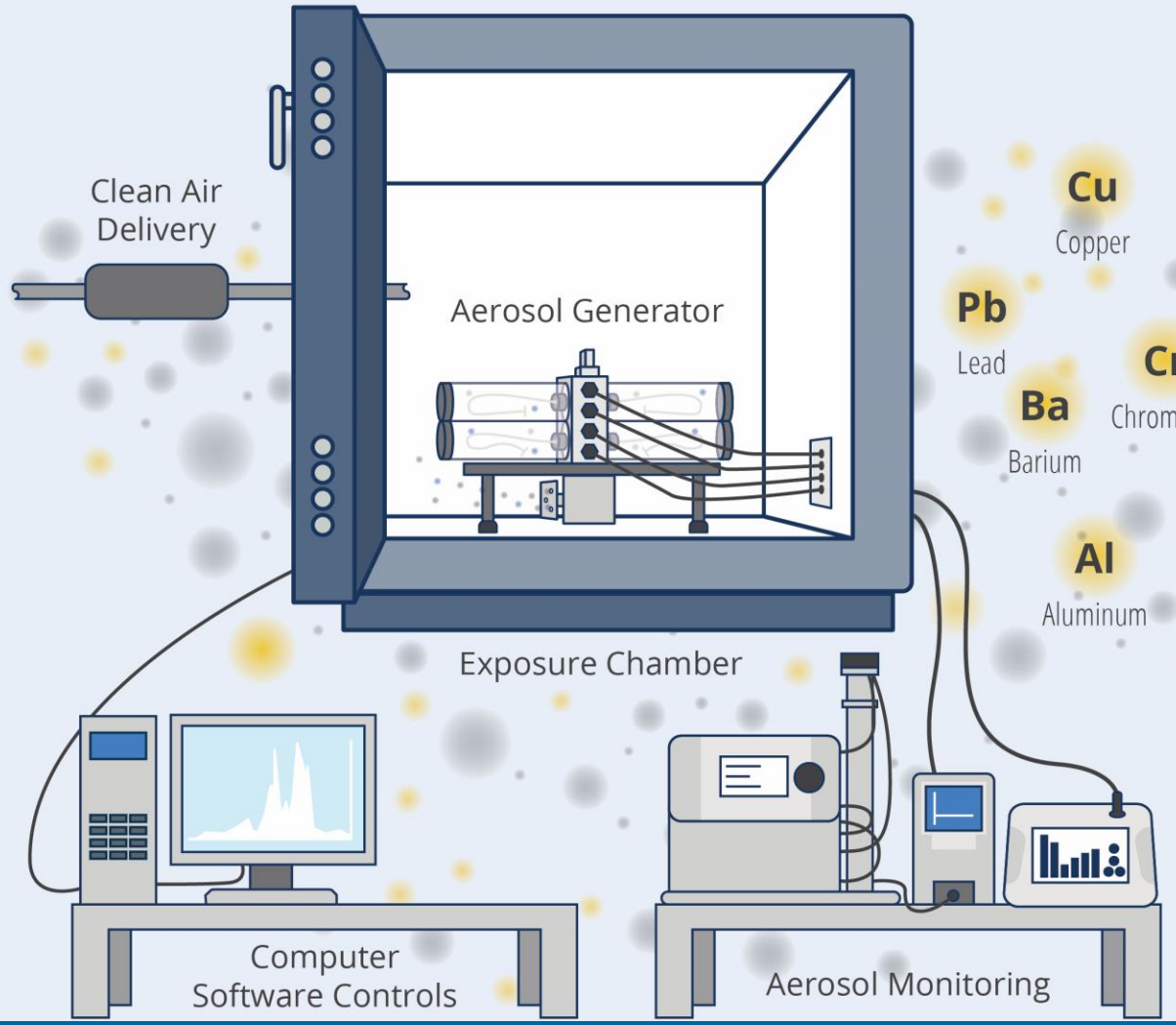
DEVICE TYPES

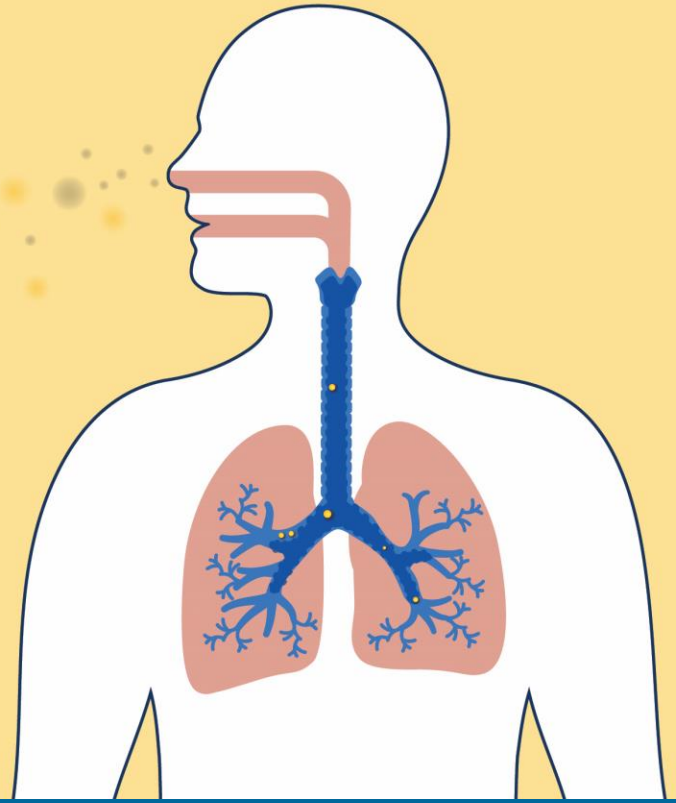
JUUL

EXPOSURE AND SAMPLING PLATFORM
ENDS Aerosol Generation System (EAGS)



ENDS MEDIATED ADVERSE RESPIRATORY OUTCOMES

- Reactive oxygen species
- Oxidative stress
- DNA damage
- Cellular injury



Emerging Risk:

Increased Pollutant Exposure from Climate & Weather

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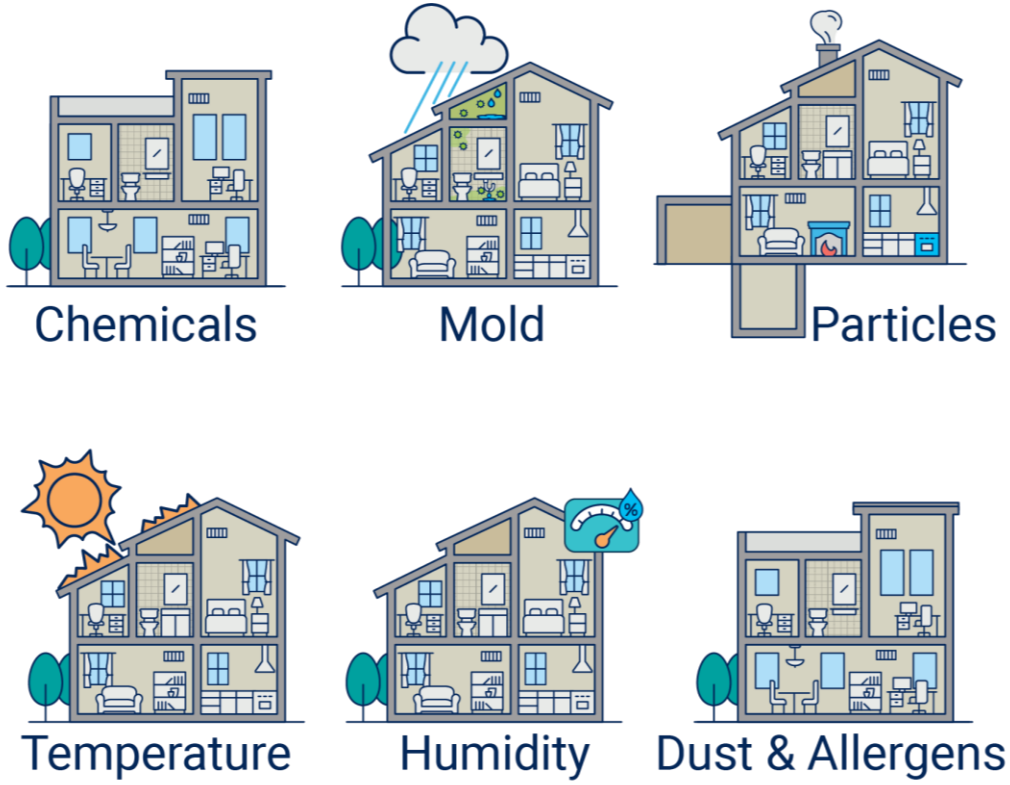
Stressors: External and Internal



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THE EFFECT OF TEMPERATURE AND MOISTURE ON A BUILDING'S INTERIOR

MOLD GROWTH

Stachybotrys chartarum (greenish-black mold)

Can grow on material with a high cellulose content (fiberboard, gyp board)

CHEMICAL OFF-GASSING

When temperature and humidity levels rise, the ability of certain chemicals to "migrate" from a material into the air and settled dust

Emerging Risk:

Changes in cleaning practices to mitigate aerosol transmission

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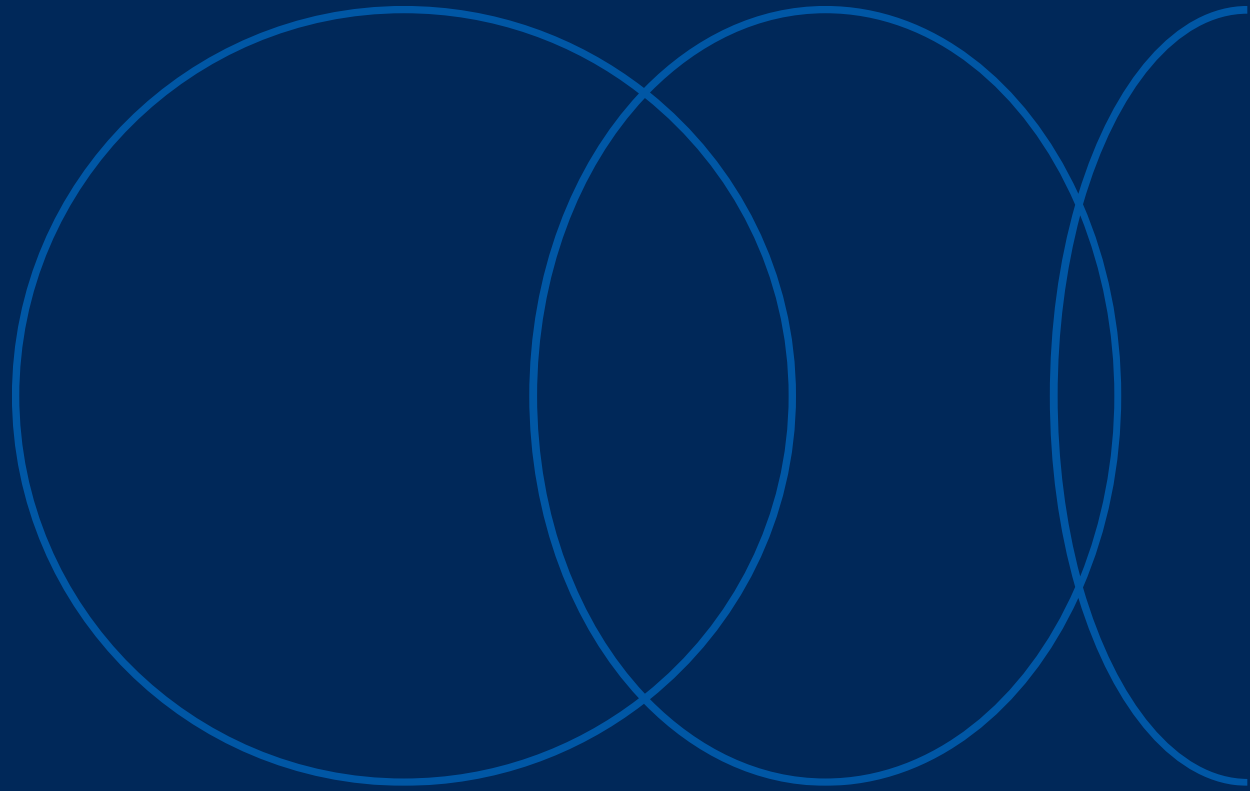
More is NOT Better!

Diluting contaminants (through ventilation) works BETTER than killing contaminants (through disinfection).

Impacts on IAQ – Case Studies from CIRI Research



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1

Vaping

2

3D Printing

3

Extreme Heat and the Built Environment

Case Study 1

Examining the Role of Vaping Behavior on Secondhand Chemical Exposure and Inhalation Risks

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ELECTRONIC NICOTINE DELIVERY SYSTEM (ENDS)

Tanks or Mods

- 3rd Generation
- Rechargeable
- Reusable
- Highly modifiable
  - = “Mod

Pod Mods

- 4th Generation
- Rechargeable
- Prefilled/refillable “Pod”
- Modifiable “Mod”
- Nicotine salt
  - Lower pH
  - Allow high levels of nicotine to be inhaled with less irritation

Disposable Mods

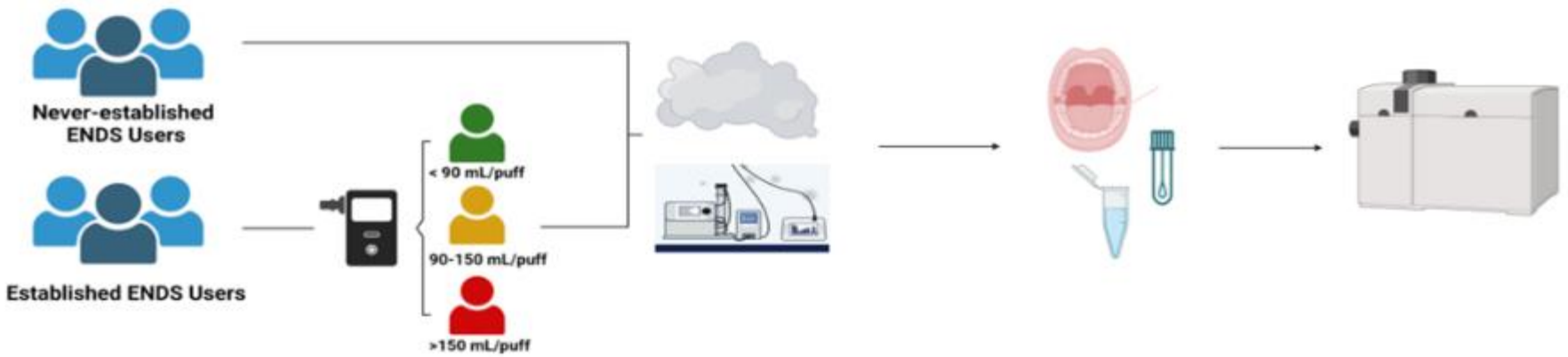
- 4th Generation
- Non-reusable
- Non-refillable
- Most recent models provides the feature to recharge the device but not the e-liquid

E-liquids

-Menthol -Cotton candy -Sour Candy -Golden Tobacco -White Gummy -Kiwi Strawberry -Iced Mango Berry – Passion Fruit Guava – Energy Drink Skittles - Nicotine: 3-5%

Human Subjects and Study Design

Secondhand Vaping Assessments



Recruitment:

- Healthy adults, ages 18-35 years.
- No dual tobacco use or use of other nicotine.

Puffing Topography Assessment:

Puff volume, flow rate, inter-puff interval, puff duration.

Particle Monitoring:

Scanning Mobility Particle Sizer, Optical Particle Sizer, VOC and aldehyde monitoring.

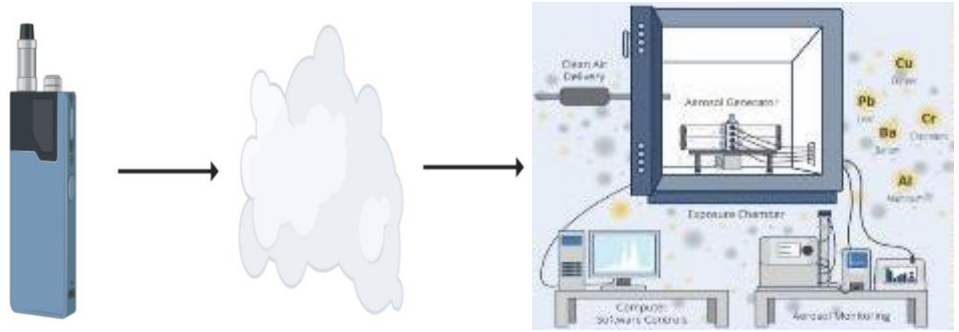
Oral Heath Exam and Biosample Collection:

Collection of saliva, gingival epithelial swabs and plaque samples for analysis.

Integrative Data Analysis:

Bioinformatics, particulate/VOC, health inhalation risk and implications.

Firsthand Vaping Assessments



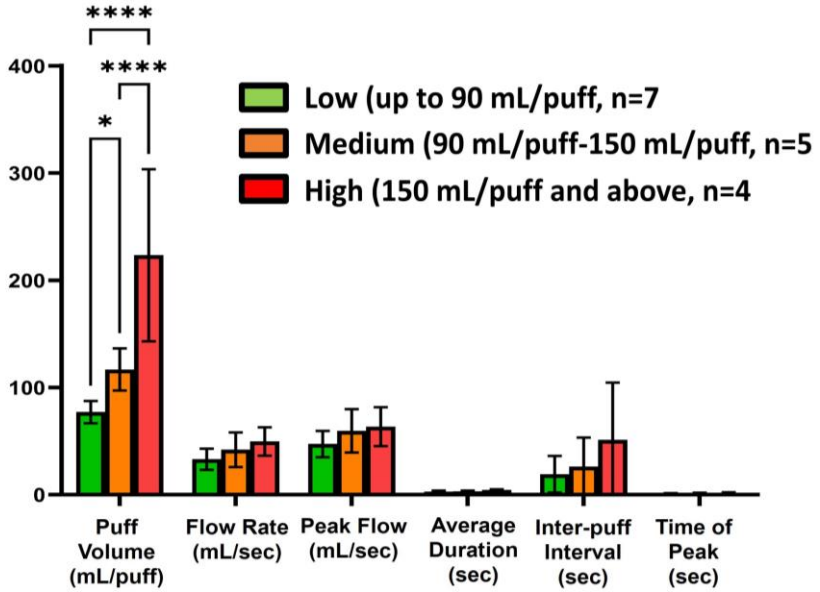
Applied puffing topography assessment parameters to an ENDS Aerosol Generating System and primary emissions were characterized.

PUFFING TOPOGRAPHY:

Establishing Behavior Based Exposure Mediators

PCA reveals:

- Puff Volume
- Flow rate
- Highest correlation and contributed significantly to the explained total variance.



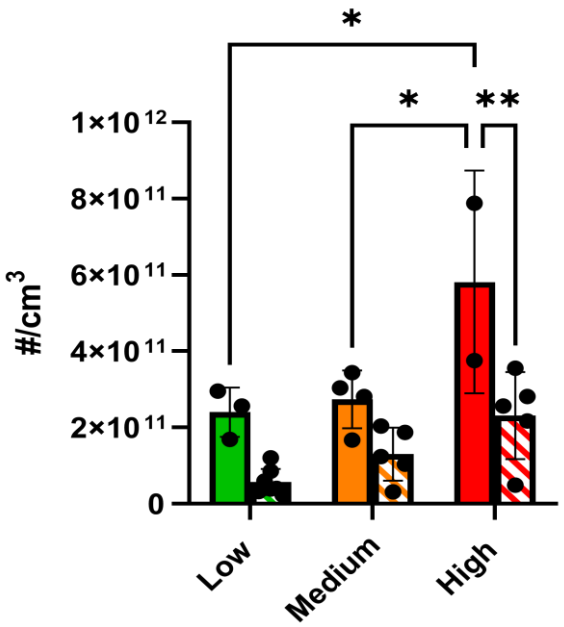
Groupings were not dependent upon:

- Participant sex
- Brand or nicotine level used
- Exhaled forced vital capacity

THE RELATIONSHIP BETWEEN EXPOSURE MEDIATORS:
Particle Emissions

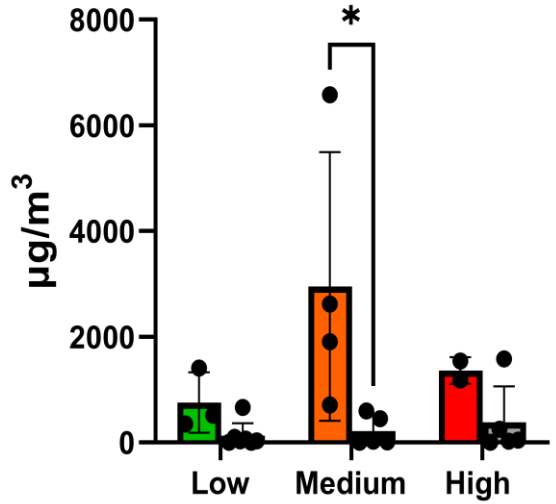
FIRSTHAND EMISSIONS
SECONDHAND EMISSIONS

A. Total Particle Count



- Puff volume and flow rate mediate total particle counts:
- Higher the puff volume and flow rate the more particles are generated by device and user.

B. Total Particle Mass



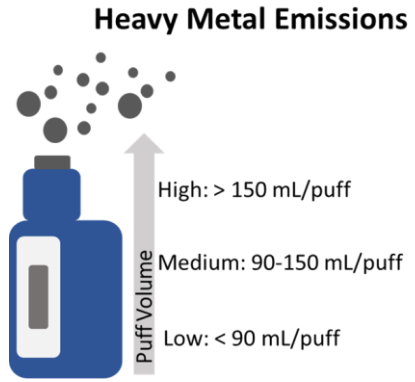
- Puff volume and flow rate mediate total particle mass:
- Higher the puff volume and flow rate, more particle mass is emitted by the device and user.

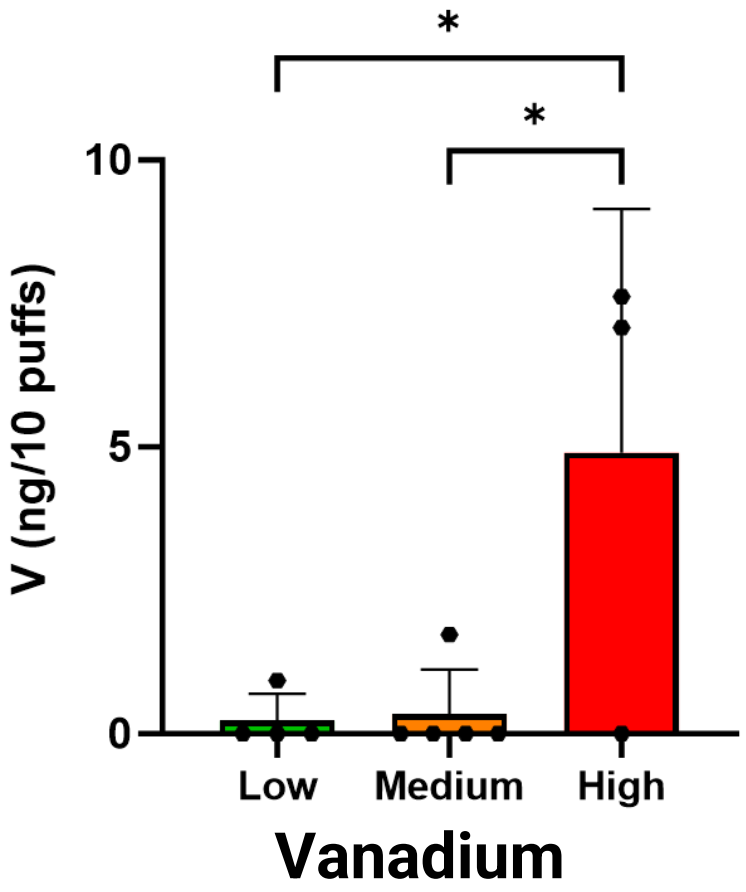
C. Geometric Mean Diameter

- Puff volume and flow rate mediate impact emitted particle diameter
- Emitted particles are all within same nano-range.

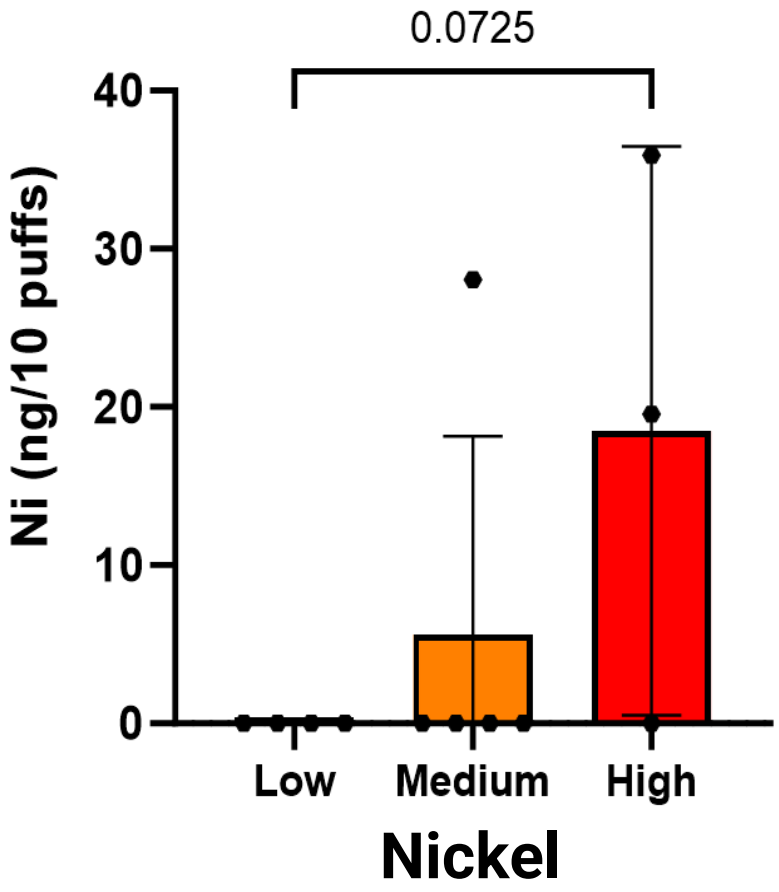
THE RELATIONSHIP BETWEEN EXPOSURE MEDIATORS:

Metal Emissions

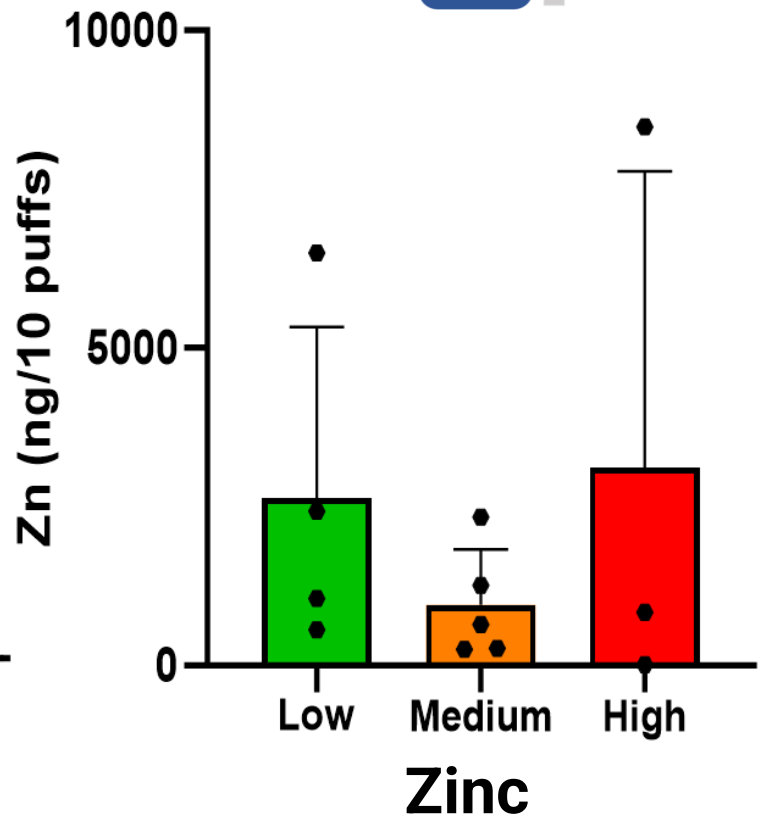




Vanadium



Nickel

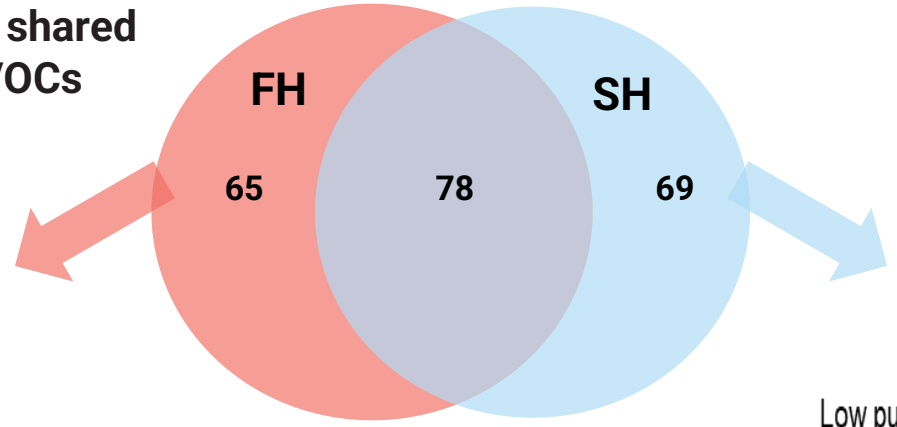


Zinc

PUFF VOLUME BASED VOCS EMISSION:

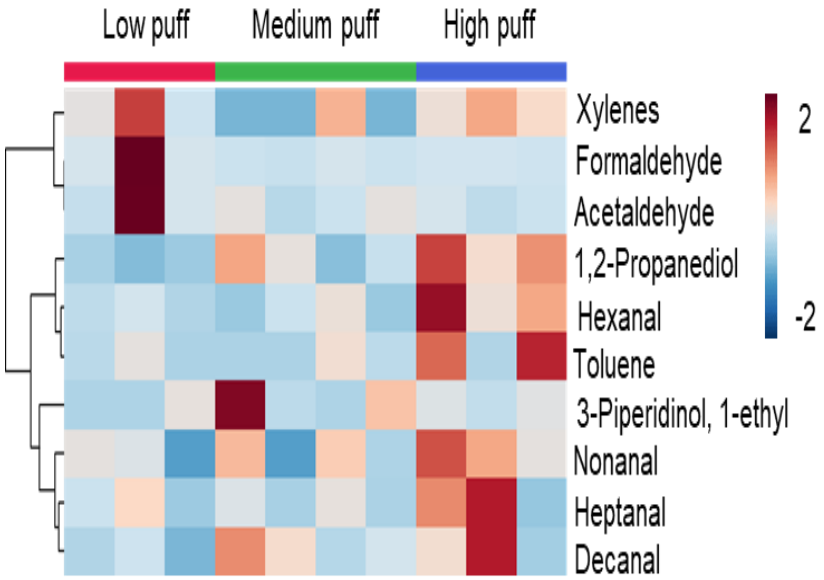
Comparison of Firsthand and Secondhand Vaping Exposures

Firsthand and secondhand emissions shared more than 50% of the total detected VOCs

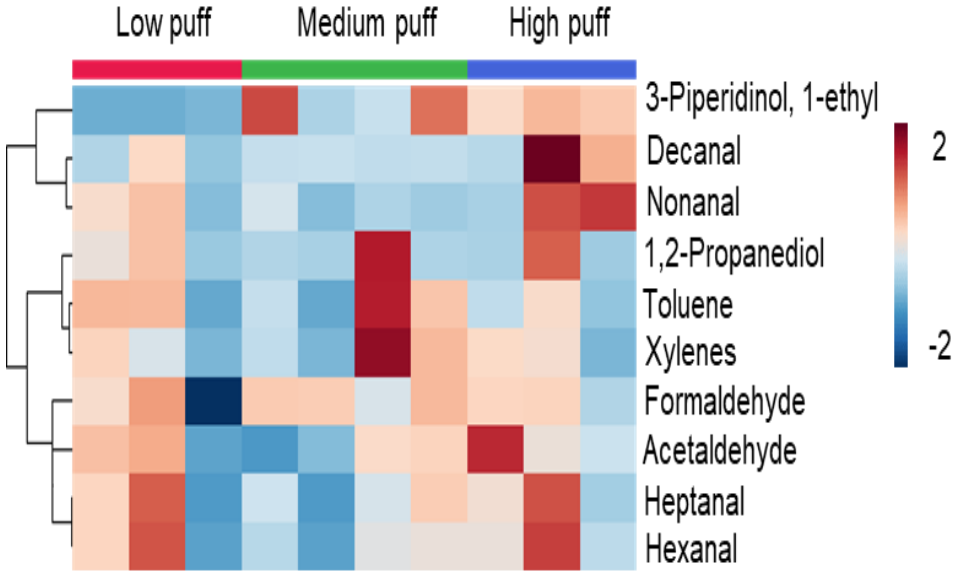


Top Ten Shared VOCs

Firsthand VOC Emissions

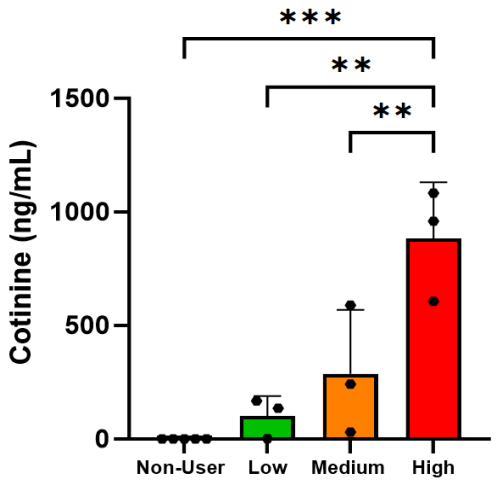


Secondhand VOC Emissions



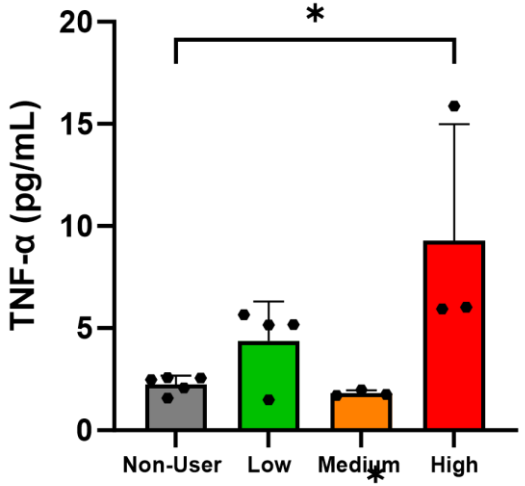
RESPIRATORY HEALTH IMPLICATIONS:

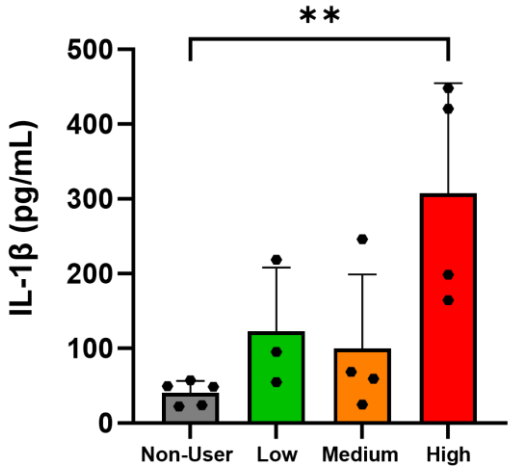
Biomarkers of Exposure and Lung Injury

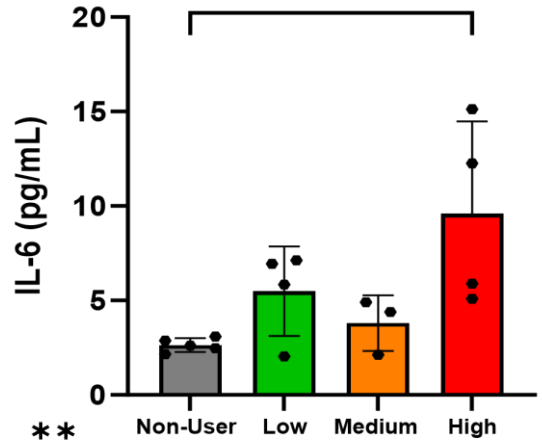


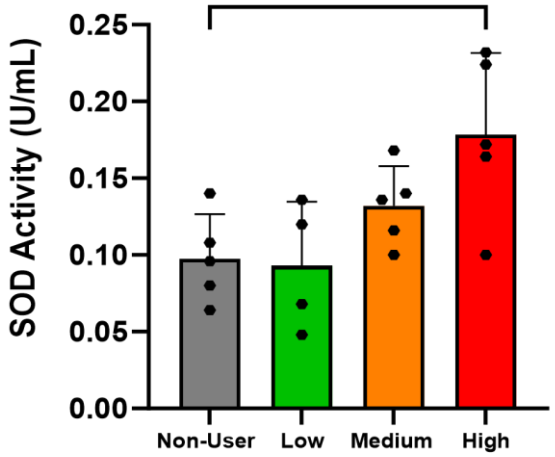
Oxidative Stress and DNA Damage

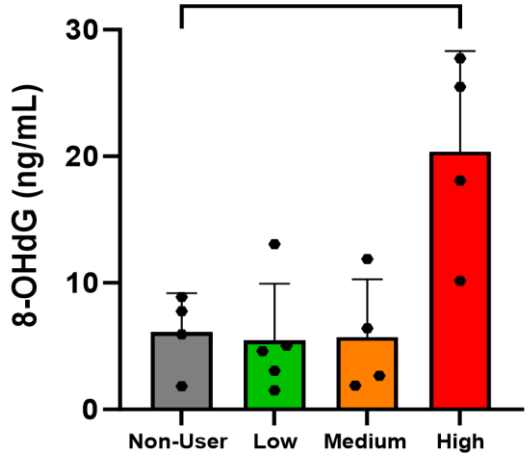
Pro-Inflammatory Cytokines











Conclusions and Future Directions

1) Puffing topography analysis revealed potent exposure mediators including puff volume and flow rate.
2) Increasing levels of particles and VOCs in firsthand (device) and secondhand emissions (user) were observed due to increasing puff volumes.
3) Significant increase in pro-inflammatory cytokines, which can cause lung inflammation and reduced epithelial barrier integrity leading to reduced lung function.

Develop Consumer Guidance Document

- Highlight how unique consumer vaping patterns and preferences can enhance exposure to:
  - Particulates
  - Metals
  - VOCs
- Illustrate inhalation and oral health risks:
  - ENDS users
  - Family members, friends, or bystanders

Case Study 2

Metabolic and Toxicological Effects of 3D Printer Particulate Emissions Found within High Schools

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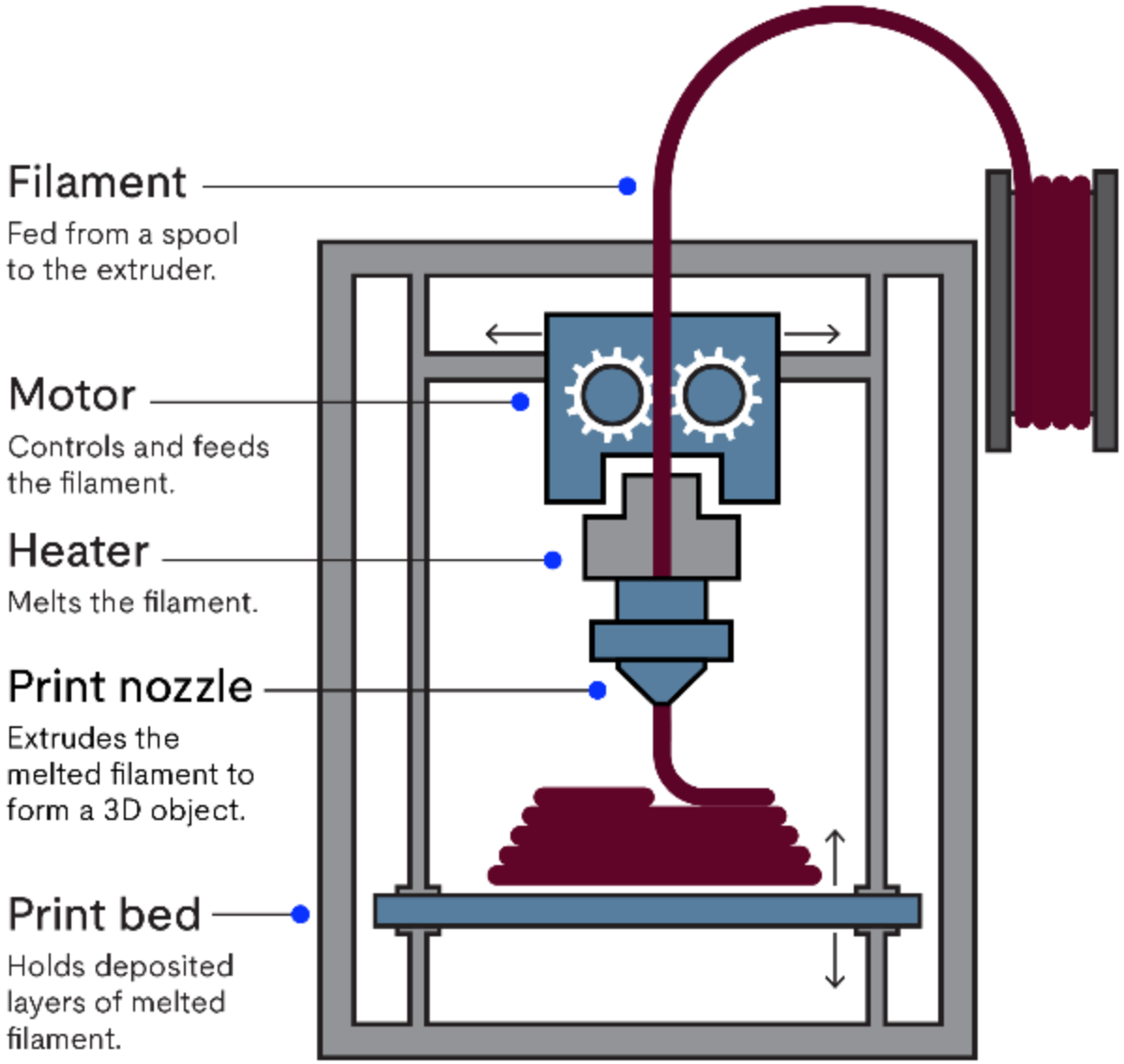
Exploring 3D Printer Emissions in HS Classrooms

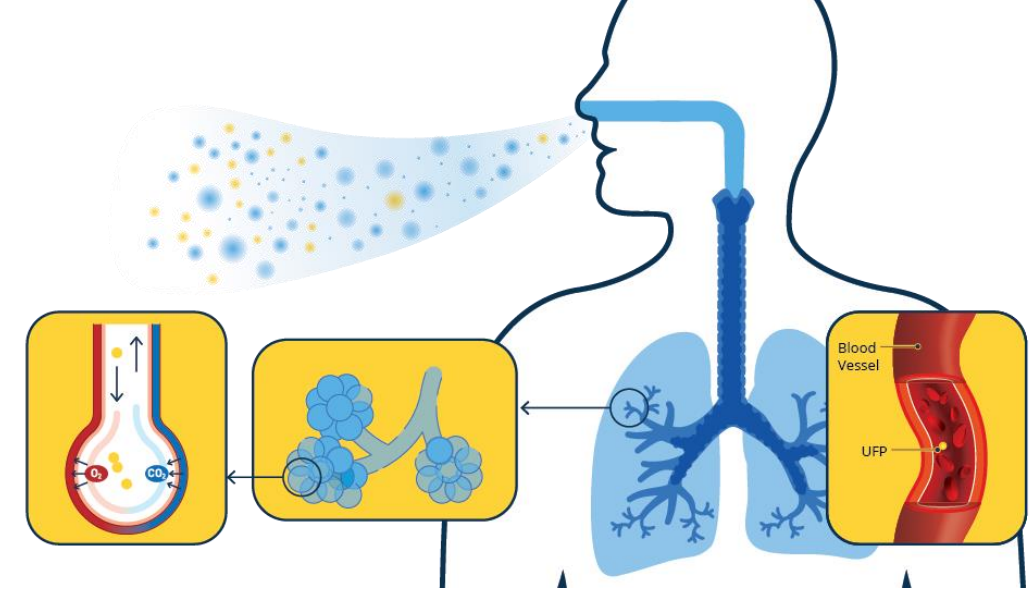
- Three-dimensional (3D) printer usage across educational settings has increased.
- Health concerns have emerged due to chemical and particle emission exposures during standard operation.
- However, little is known about the impact of 3D printer emission exposures on respiratory health.

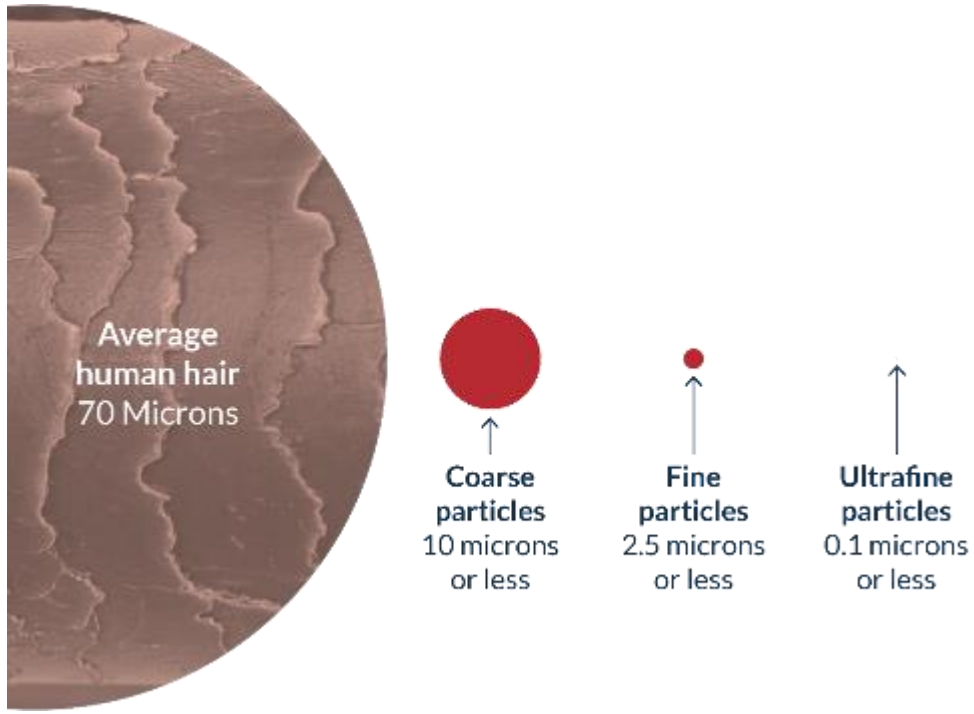
Fused Filament Material Extrusion Process



Particle Emission

- Particle emissions from 3D printers could reach up to 1,000,000,000,000 (10^{12}) particles per hour
- Particle exposure may cause health problems, including:
  - Eye, nose and throat irritation
  - Aggravation of coronary and respiratory disease symptoms
  - Premature death in people with heart or lung disease
- Most are ultrafine particles (UFPs) smaller than 100 nanometers in size, which **present a major health concern**





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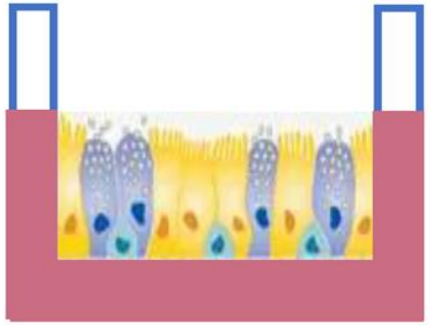
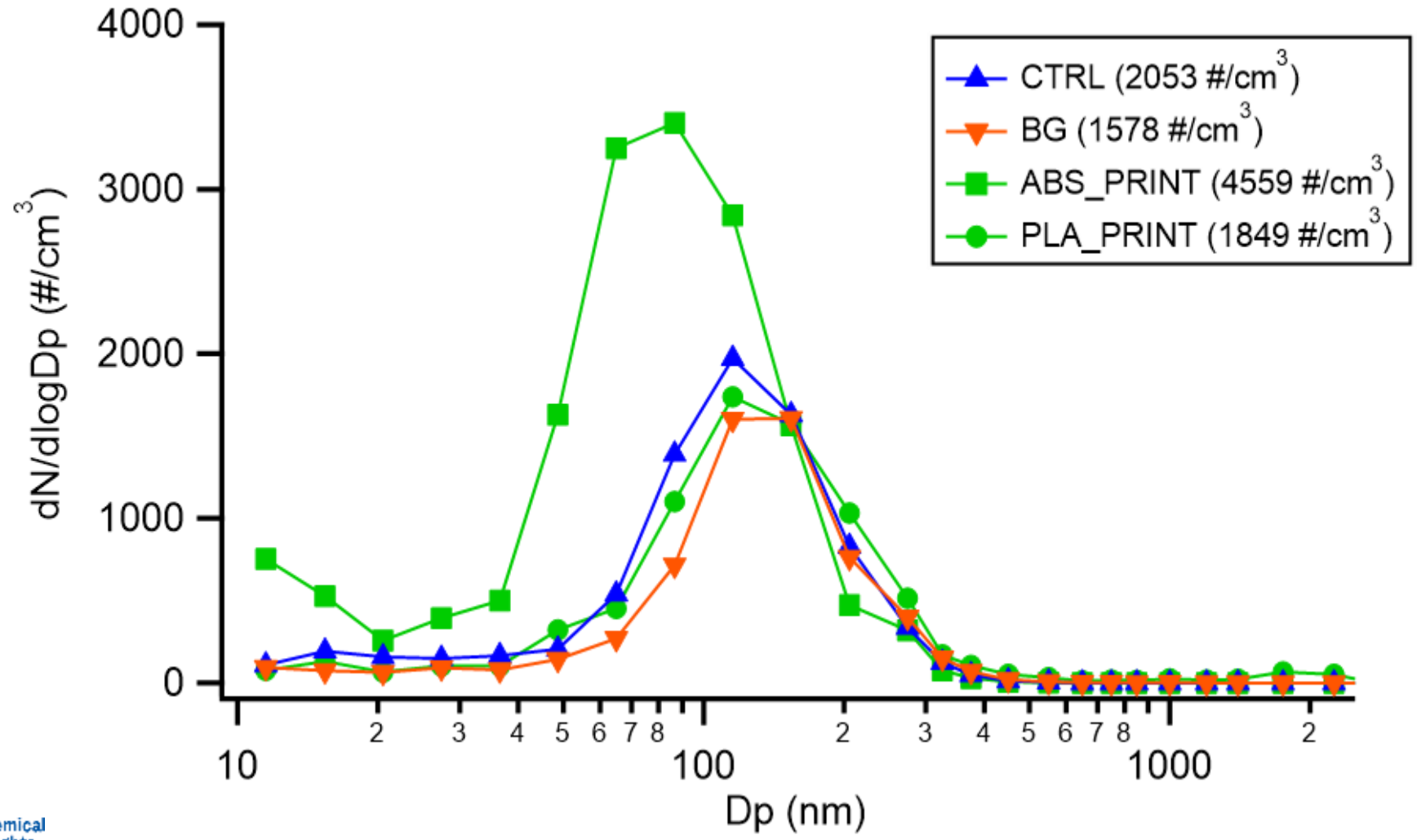
Field Study Methods

3D Printer Operation	Monitor and Sample Particulate Emissions	Expose Small Airway Cells	Toxicological Analysis	In Silico Analysis
				
3-hr operation with ABS or PLA filaments	Scanning Mobility Particle Sizer (10-420 nm) Optical Particle Sizer (0.3-10 µm)	Extract PM and expose cells to 5 and 10 µg/mL	MTS viability assay DNA damage Cytokine release HPLC-MS metabolomic profiling	Pathway enrichment analysis

3D Printer Emission Profiles



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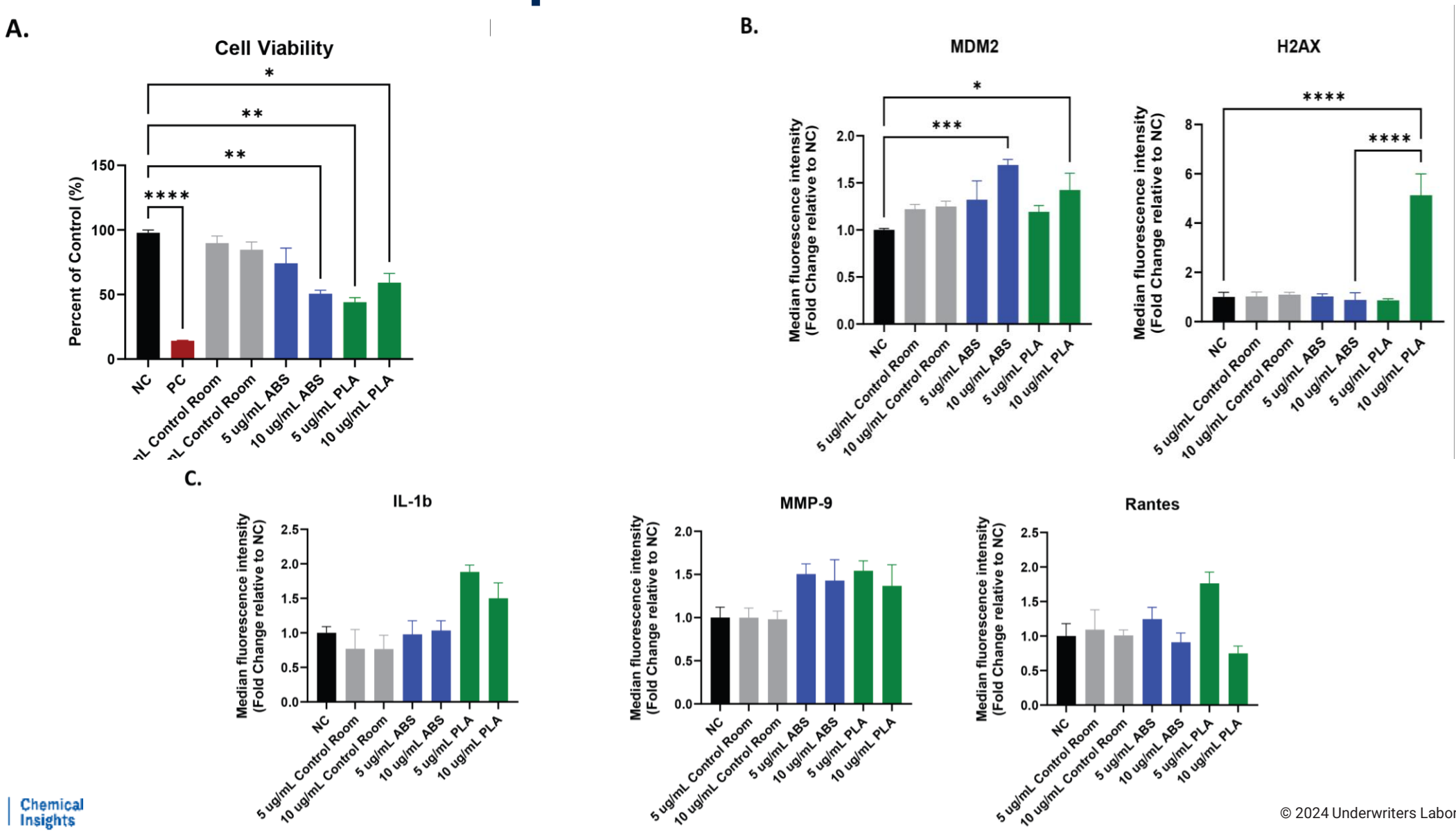
3D Printer Emission Impact on SAEC



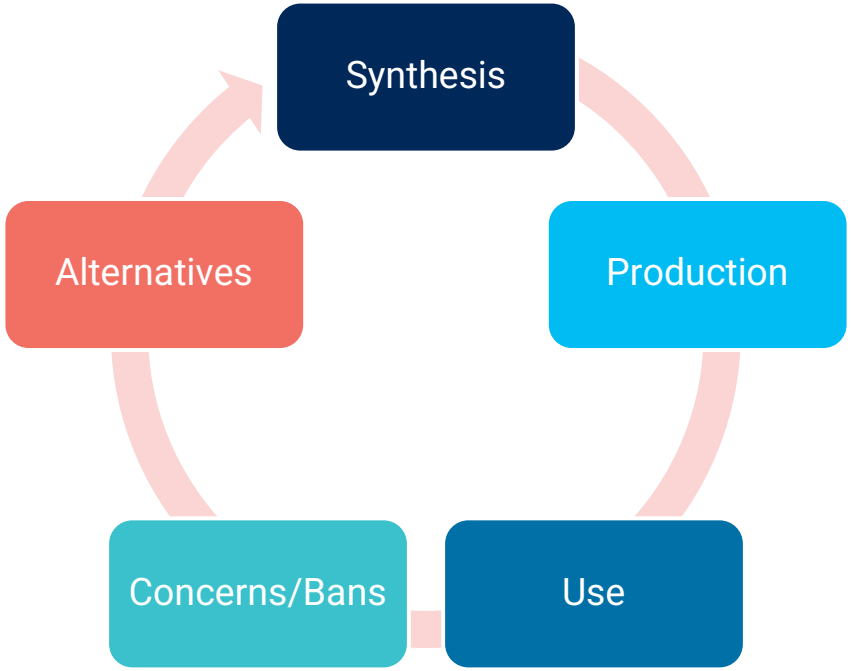
Conclusions

- ABS and PLA filament emissions have distinct aerosol properties that led to differences in the estimated inhaled and in vitro deposited doses.
- Differences in dose led to corresponding filament specific differences in cell viability and inflammatory responses.
- While both ABS and PLA emissions significantly increased MDM2, PLA emissions exposures additionally increased gamma H2AX.

Case Study 3

The effect of moderate temperature rise on emitted chemicals from modern building materials

Background

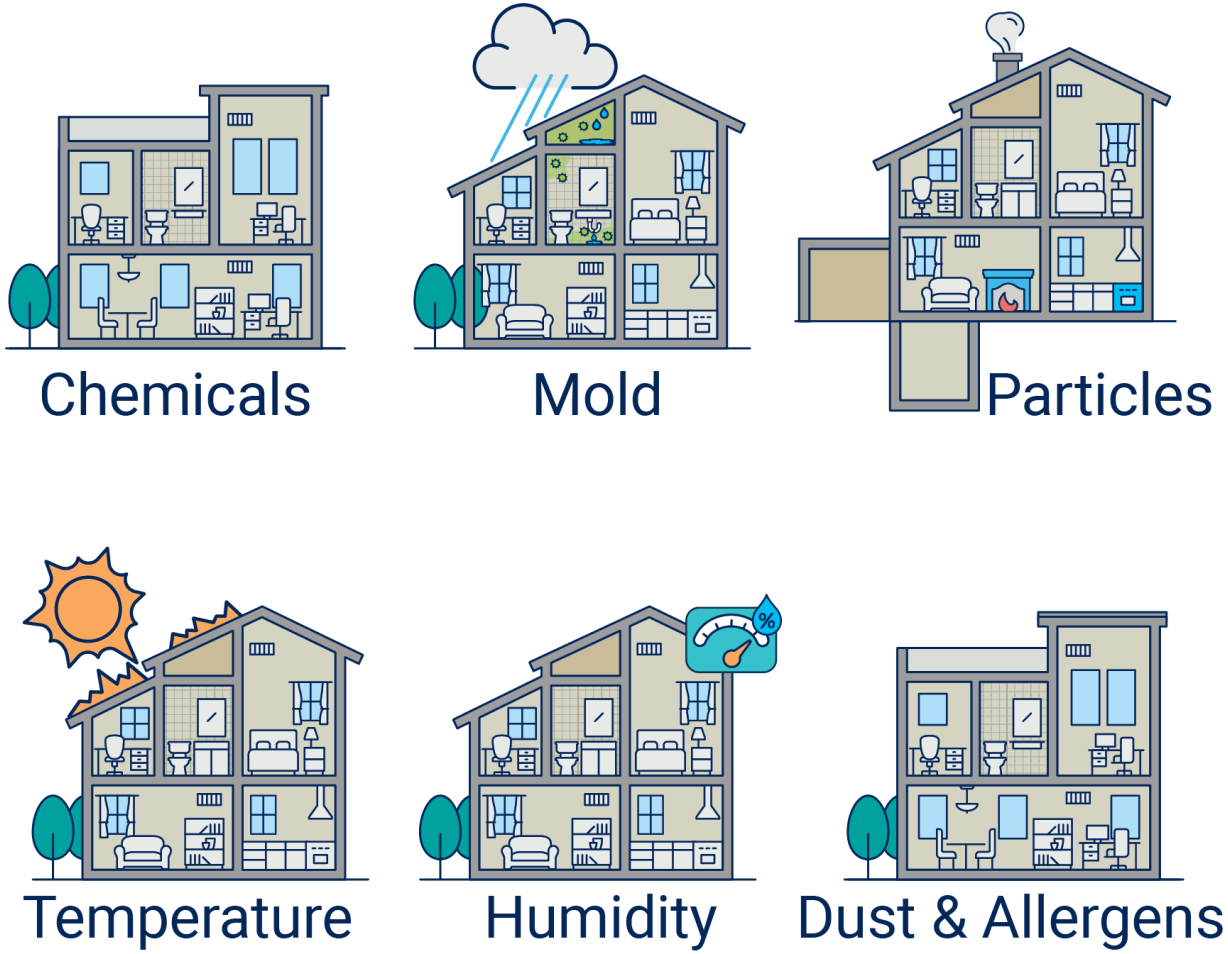


The Global (Chemical) Landscape

- Chemical pollutants are preeminent and numerous
  - 40-fold increase during the last 150 years
- "Chemical intensification"
  - Industry → daily use
  - Legacy and emerging
    - Pesticides, PAHs, heavy metals, VOCs, PFAS & microplastics

Indoor air quality

- Internal chemical landscape
  - Indoor air quality poorer than outdoors
- Can building materials behave differently based on these stressors?
  - There are links between temperature, humidity, and chemical emissions.
  - One example: formaldehyde (CH_2O)
    - FEMA trailers, Hurricane Katrina (temperature and humidity)

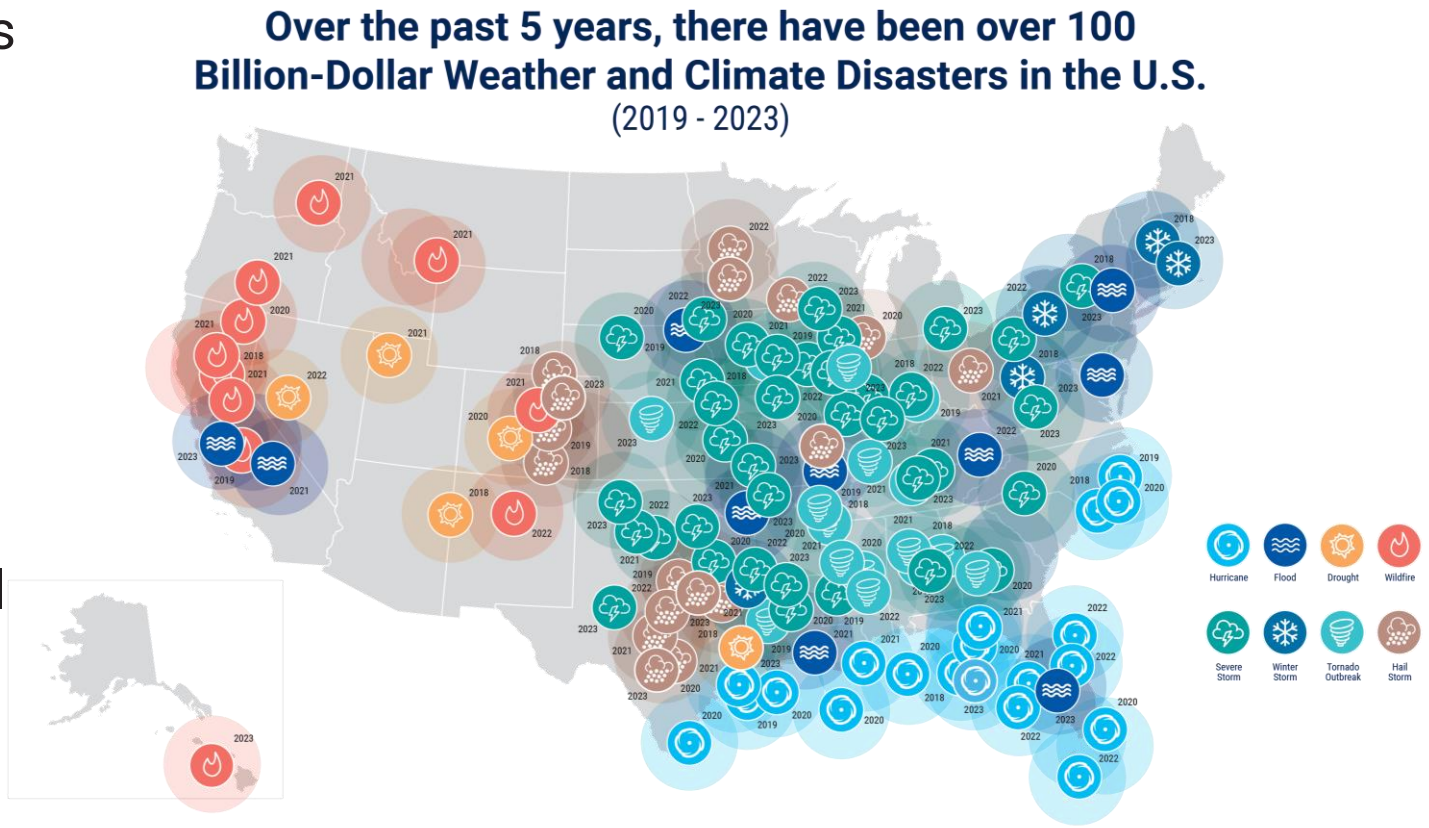


The investigation

- Lack of literature on building materials themselves – just indoor environment as a whole and only certain materials
- Introduce deliberate design questions and choices and *real-world* environmental conditions

Big picture questions:

1. What are the effects of ***moderate*** temperature rise on building material chemical profiles?
2. Can the current testing and certification standards adequately address these adverse climate events now and in the future?



Study Design and Methods

Materials Selection

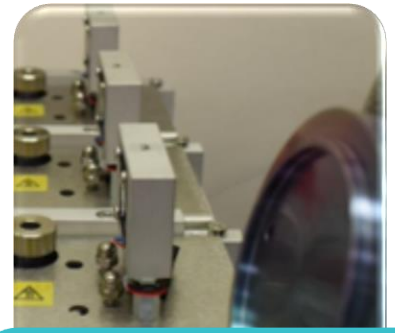
→ Representative indoor materials were studied

Microchamber Assessments

→Four sampling chambers with individual sampling port

→Two temperature setpoints:

- Room temp: 23℃
- Elevated temp: 35℃



Sampling Conditions

→Constant flow (0.2 L/min) to sampling tubes

→Tenax TA for VOCs – 15 minutes

→DNPH for ALDs – 30 minutes

VOC/ALD Characterization

→TD-GC/MS

→HPLC

Material Sample Details







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Increase in TVOC and TALD (In Elevated Conditions)

TVOCs

Material	% Increase
MDF	-12%
Insulation	30%
Drywall	54%
Natural Wood Flooring	89%
Engineered Wood Flooring	405%
Laminate Flooring	334%
Vinyl Flooring (1)	241%
Vinyl Flooring (2)	37%
Carpet Flooring	5%
Crown Molding	291%
Baseboard	103%
Paneling, oil-finish	181%
Paneling, water-finish	10%
Wallpaper Covering	190%
Acoustic Tile	235%

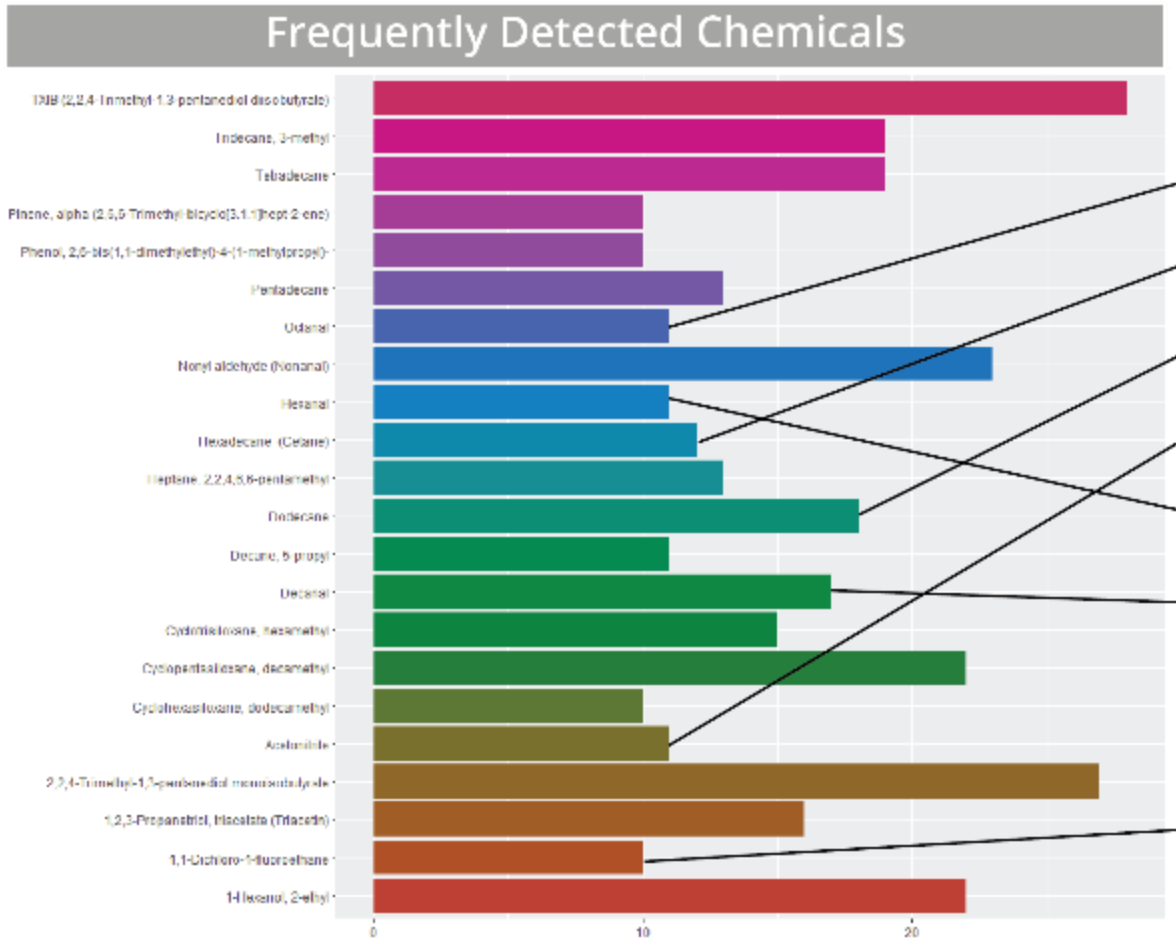
TALDs

Material	% Increase
MDF	74%
Insulation	29%
Drywall	43%
Natural Wood Flooring	98%
Engineered Wood Flooring	387%
Laminate Flooring	131%
Vinyl Flooring (1)	67%
Vinyl Flooring (2	-
Carpet Flooring	914%
Crown Molding	186%
Baseboard	114%
Paneling, oil-finish	-78%
Paneling, water-finish	23%
Wallpaper Covering	-
Acoustic Tile	-

This demonstrates that current certifications that use TVOC limits may not be applicable in expanding real word scenarios.

Frequently Detected Chemicals (Across Material Types)

Building Materials
Acoustic tile
Baseboard
Carpet flooring
Crown molding
Drywall
Insulation
Laminate flooring
MDF
Natural wood flooring
Paneling, oil-finish
Paneling, water-finish
Vinyl flooring
Wallpaper covering
Wood flooring



Irritants
Octanal
Hexadecane (Cetane)
Dodecane
Acetonitrile

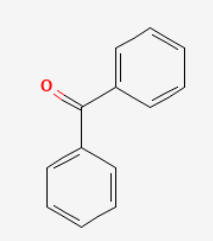
Renal Toxicants
Hexanal
Decanal

PFAS-like
1,1-Dichloro-1-fluoroethane

New Chemicals of Concern
(from vinyl flooring at elevated temperature)

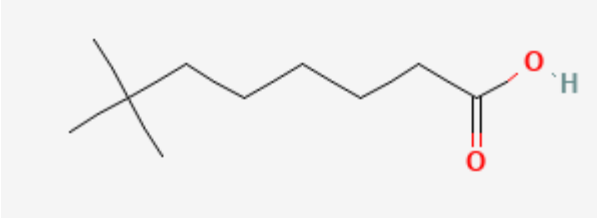
Benzophenone

- IARC Group 2B carcinogen
  - Possible human carcinogen
- Endocrine disrupting chemical
  - Estrogenic activity
- Neurotransmitter inhibitor
  - Acetylcholinesterase inhibitor



Neodecanoic acid

- Toxic pneumonitis
  - Chemically induced pulmonary inflammation
- Dermal/ocular irritant
  - Contact dermatitis and ocular edema



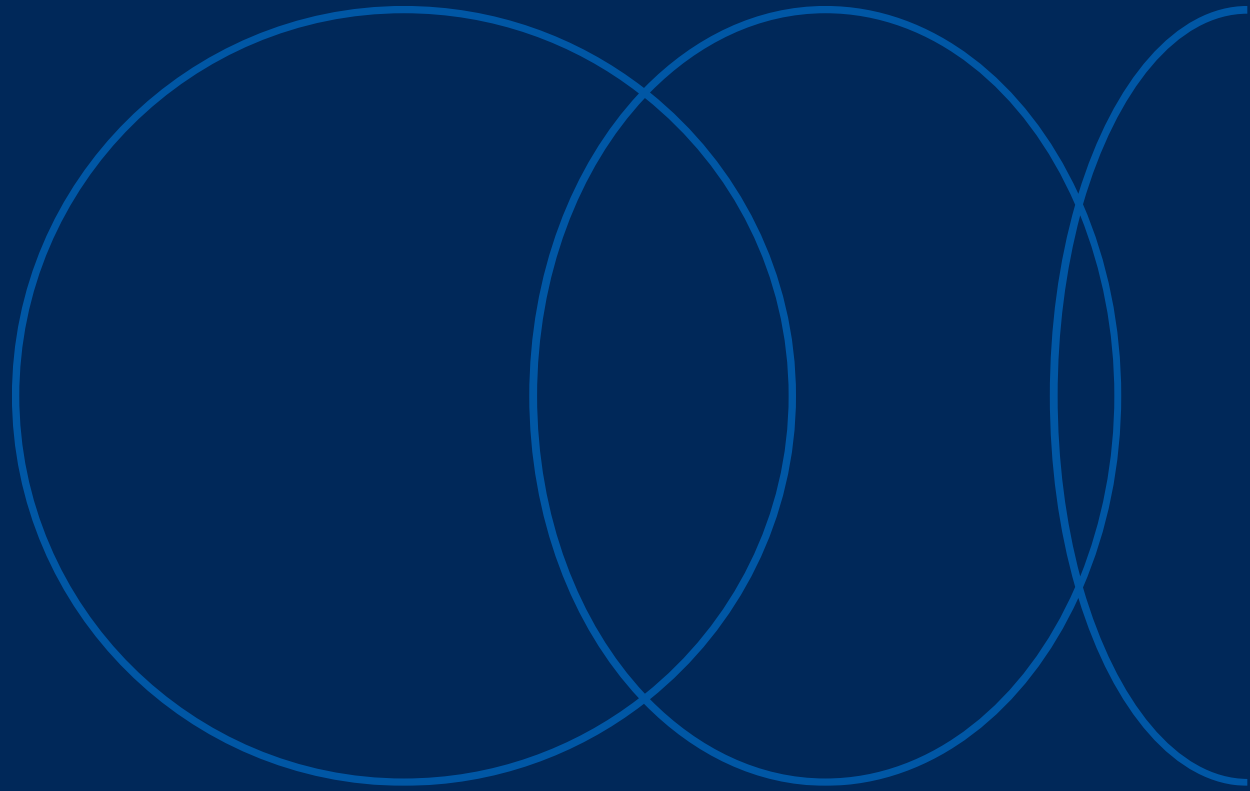
Conclusions

1. Many materials indicated increased emission rates of VOCs at 35°C

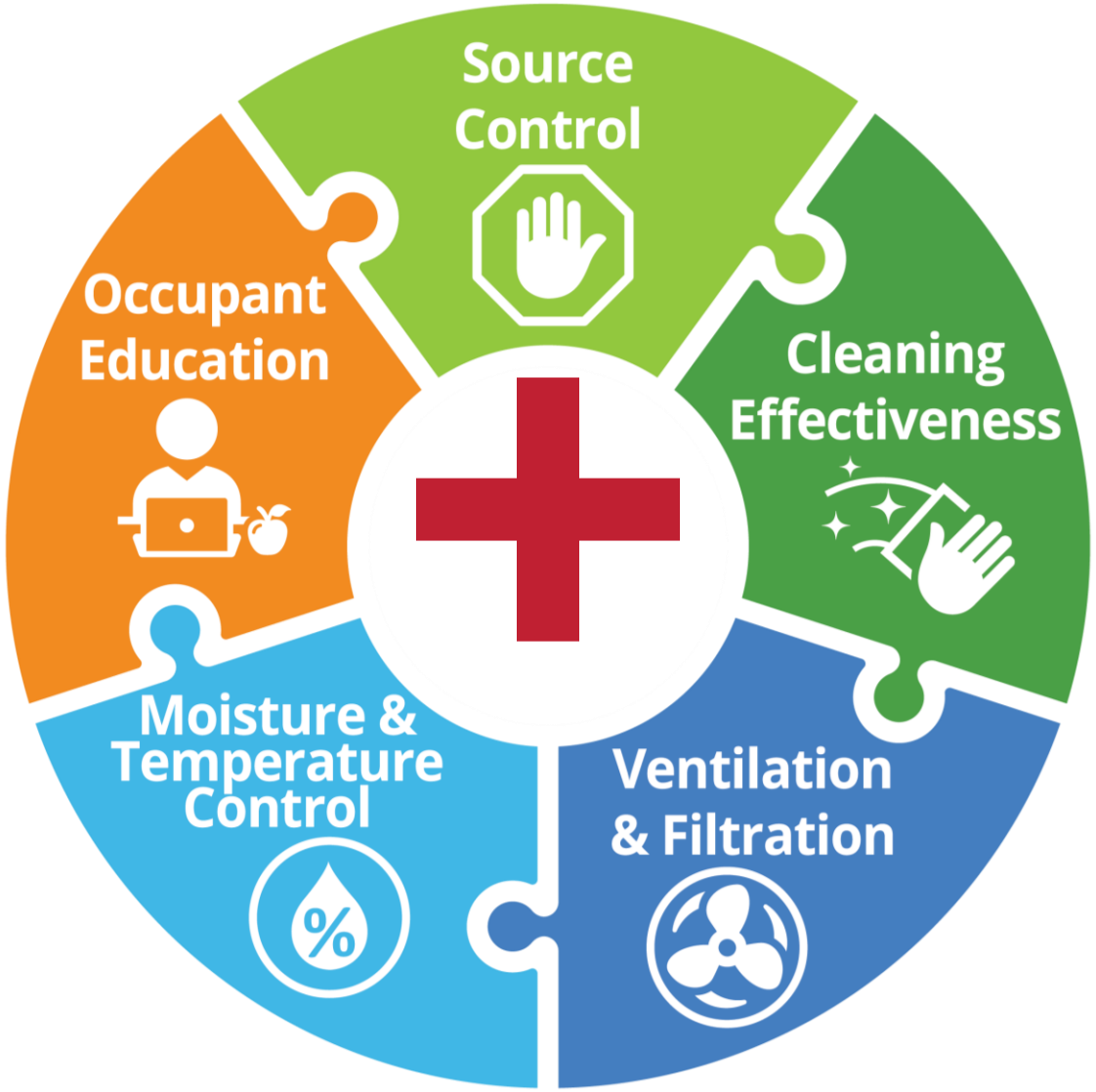
2. Materials with higher surface area in the built environment are of the most concern and deserving of greater scrutiny, especially in vulnerable populations

3. An accurate picture of chemical load in the indoor environment is still needed based on the climate events predicted in the near future.

What Can We Do?



Strategies for Healthy Indoor Air Quality in Schools



One of the most effective ways to minimize exposure to indoor air pollutants is to **prevent emissions in the first place**

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Source Control Strategies

Specify/buy certified or verified low-emission and specific chemical-free products.

Air products out before use.

Require all vendors/ suppliers to use verified low-emission/ specific chemical-free products.

Use products as recommended.

Dispose of products safely.

Cleaning Effectiveness

Practice good source control. Only use disinfecting products approved by the US EPA.

Vacuum floors, textiles, and furniture with a HEPA vacuum.

Remove dust from all flat surfaces (not just floors).

Focus cleaning on high touch surfaces.

Use cleansers in well-ventilated spaces and open windows.

Implement routine cleaning programs to avoid build-up of settled dust and films.

Ventilation and Filtration

A properly working HVAC system dilutes pollutants and transports them outside.

Incorporate at least 15-20% outdoor air at all times.

Filter fresh air with the highest MERV filter possible.

Consider building-specific requirements (i.e., HEPA filtration in healthcare).

Check ductwork for leaks to reduce contaminants in the plenum space.

Return air should never be expelled into an open plenum.

Maintain operational strategies that keep the system running at least 2 hours before & after occupancy.

Plan ongoing maintenance (i.e., changing filters).

Supplemental Air Cleaning

Integrate air cleaning technologies directly into the HVAC system to clean the conditioned air that will be circulated throughout the building.

Use of stand-alone air cleaners to supplement the HVAC system in high volume areas or areas with potential pollutants.

Moisture & Temperature Control

Maintain indoor humidity levels between 40 and 60%.

Maintain temperature range based on ASHRAE 55 (67-82 °F)

Use dehumidifiers.

Repair all chronic water leaks or entry points to prevent water intrusion and damage.

Dry wet materials quickly.

Remove chronically wet materials.

Independent, Third-Party Resources

Source Control:

- GreenScreen® For Safer Chemicals
- UL GREENGUARD Certification Program
- EPA Greener Products and Services

Cleaning Effectiveness:

- EPA-Registered Disinfectants
- Green Seal
- The CIMS Standard (ISSA)

Ventilation and Filtration:

- ANSI/ASHRAE Standard 62.1-2022, Ventilation and Acceptable Indoor Air Quality
- EPA Clean Air in Buildings Challenge

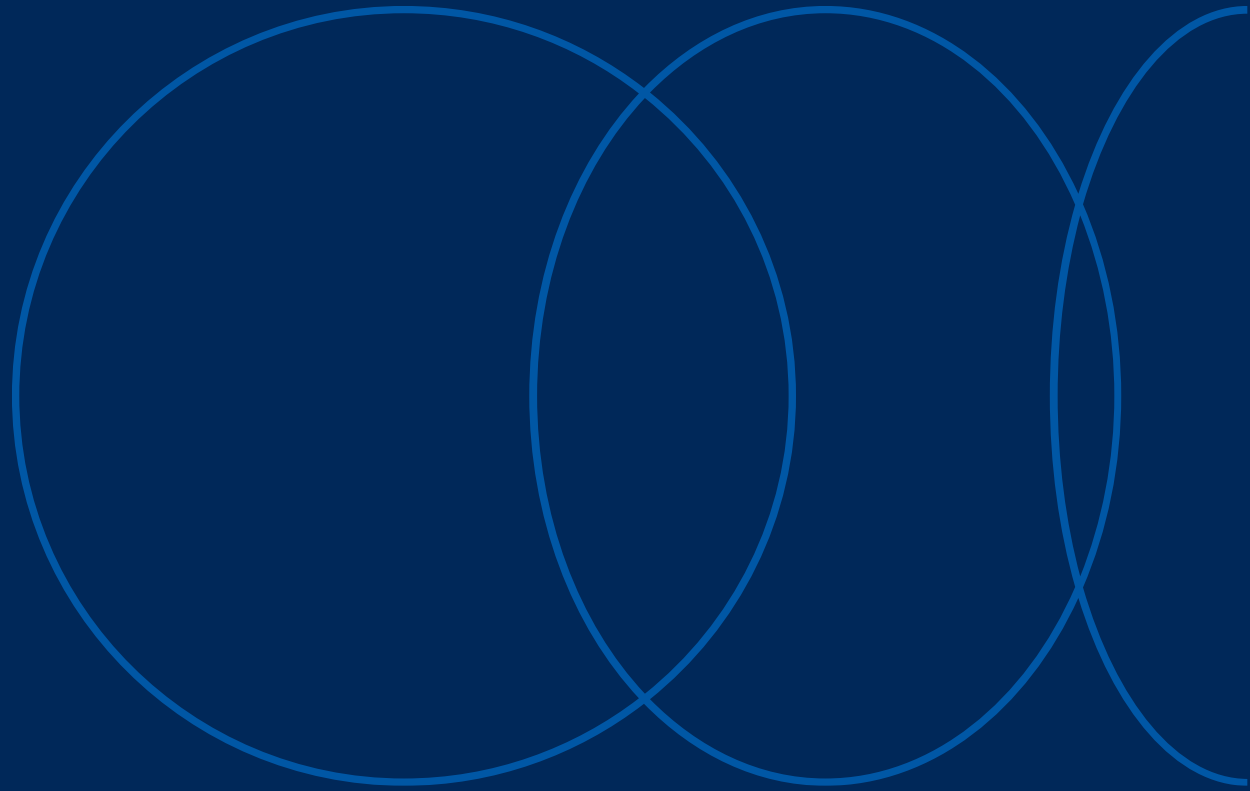
Stand Alone Air Cleaners:

- Harvard Portable Air Cleaners
- NIH Selection and Use of Portable Air Cleaners

Facility Management

- GSA Sustainable Facilities Tool
- OSHA Building Operations and Management
- Whole Building Design Guide: Sustainable O&M Practices

Discussion and Q/A



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