A Novel Wearable Carbon-Based Material to Shield Aircrews from Cosmic Radiation

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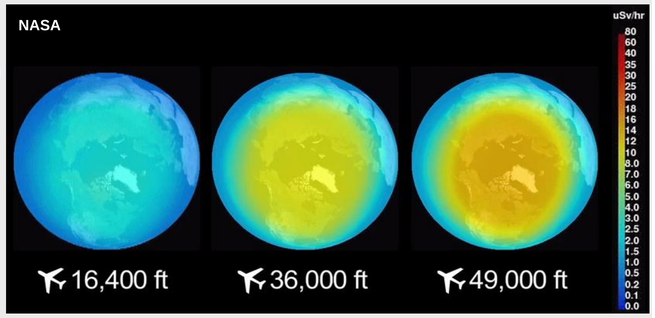
University of CINCINNATI

1. Background

- Source of ionizing radiation at aviation altitude are Galactic Cosmic Rays (GCR), Solar Particle Events (SPE), Solar Neutron Event (SNE), Solar Gamma Ray Events (SGE)
- The radiation dose of aircrews is primarily from neutrons contributing 50% and protons contributing 15% .
- Intensity of cosmic radiation in atmosphere is 90 times higher at 30k ft. than at sea level and 2.5 to 5 times higher in the polar region than equatorial region.



- The US aircrews are occupationally exposed to the highest level of mean annual effective radiation dose among all US radiation workers [1][2].
- Currently, US aircrews are not monitored for their annual occupational radiation exposure.
- Average annual dose of US aircrews in 2006 was 3.07 mSv vs. 0.59 mSv for workers at US DOE facilities.[1].
- During pregnancy, radiation exposure is limited to 1 mSv.
- Pregnant aircrews are at high risk of accumulating radiation dose over the ICRP or NCRP limits of 1 mSv or 0.5 mSv/month, respectively. [3][4], unless her work schedule is adjusted to limit exposure.
- Wearing a lightweight smock or apron that offers shielding against cosmic radiation is a practical alternative to a work restriction for pregnant aircrew.
- We propose to explore the ionizing radiation shielding property of carbon nanotube (CNT)-boron-metal composite material that can be easily integrated into the fabric to make a lightweight, protective smock or apron for aircrews

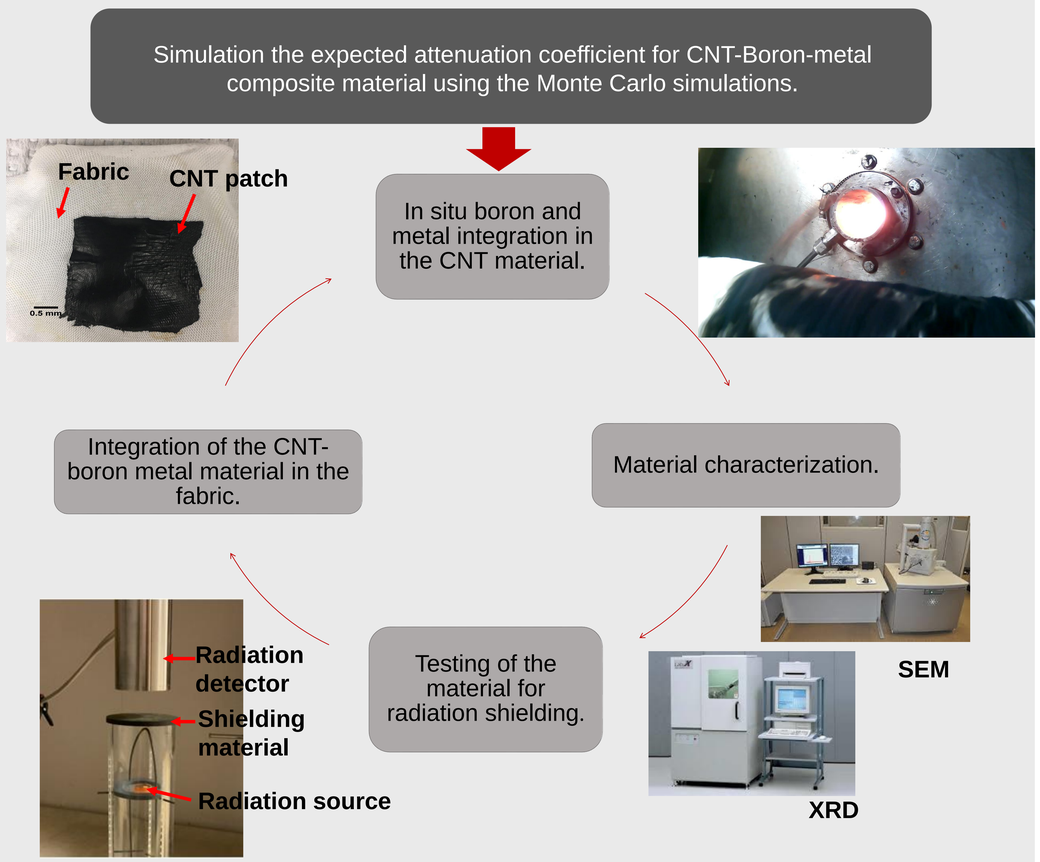
2. Objectives

- This project will investigate the radiological properties of a new wearable carbon nanotube-boron-metal composite material for use in reducing cosmic radiation exposure to US aircrews.
- The radiological properties of the new material will be determined by measuring the attenuation coefficient for a range of photon energies and absorption properties for neutrons
- The physical properties of the material will also undergo wear, tear, and wash cycle testing to determine durability as a lightweight smock or apron.

3. Relevance to NORA

Published studies suggest that flight attendants are at higher risk for reproductive and other health issues and that that this elevated risk may be due, in part, to cosmic radiation exposure. Thus, this research is relevant to NORA Cancer, Reproductive, Cardiovascular, and Other Chronic Disease Prevention (CRC) Cross-Sectors.

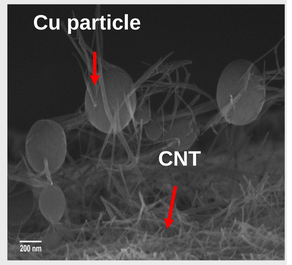
4. Research Design and Methods



- Carbon nanotube-boron-metal (bismuth, tungsten, or gadolinium or both) composite material will be synthesized through the floating catalyst method at UC Nanoworld laboratory.
- The proposed composite material will be characterized with the help of scanning electron microscopy (SEM), EDAX and TGA.
- The ability to shield gamma radiation will be determined by measuring the attenuation coefficient when the material is exposed to a range of photon energies at the Radiological Safety Engineering laboratory
- The neutron shielding characteristics of the material will be determined by measuring the response of Li6 and Li7 thermoluminescent dosimeters when exposed to Pu-Be neutron sources.
- After a successful radiation shielding tests, the composite will be integrated into the fabric and will be tested for durability, flexibility along with particle release

5. Expected Result

- Metal will be embedded in the web of carbon nanotube-boron material during high temperature synthesis.
- The percentage of the metal, carbon nanotubes, boron in the composite material will match the optimized material composition from Monte Carlo simulation for optimum shielding from galactic cosmic radiation.



- The experimental shielding measurement will be similar to the Monte Carlo simulation results.
- Integration of the CNT-boron-metal composite material into the fabric will result in a lightweight, flexible CNT-boron-metal composite fabric.

6. Impact Statement On Occupational Safety And Health

The goal of this research is to develop carbon nanotube (CNT)-boron-metal composite material for protecting aircrew from galactic cosmic and solar ionizing radiation.

7. Future Directions

- Depending upon the type of radiation, the CNT can be loaded with metal particles accordingly to provide the required radiation attenuation.
- The successful completion of this project will help us to develop a lightweight, lead free radiation shielding material for healthcare workers and researchers as well as for industry professionals working in the nuclear industry.

8. Acknowledgement

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Flexible and Low-voltage Carbon Nano Tube Heaters to Combat Cold Weather

---For fire fighters and first responders

University of CINCINNATI

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Background

- Extreme cold weather usually brings a host of health problems such as hypothermia, frostbite, flu and even heart attack. It is important for public safety employees wear appropriate gears to stay warm during emergencies and conduct their duties effectively instead of becoming casualties themselves.
- During cold weather, it is the extremities of the body which experiences poor blood circulation and results in a cold feet leading to cold stress and injuries.
- The project proposes a shoe insole made of CNT heater which is ultra-light weight, highly flexible and energy efficient with a faster heating rate.
- Among the most valuable physical properties of CNTs are their high mechanical strength, low density, high chemical resistance and electrical conductivity [1-3].
- CNT's can be drawn into fibers and sheets which makes it easier to incorporate into materials and to be used structurally [4].

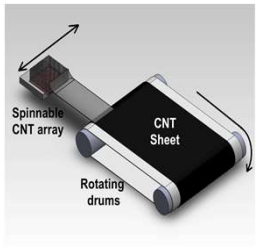
Objective

- The immediate objective is to fabricate highly efficient and flexible CNT heated shoe insoles and integrate them into the boots of the firefighters and first responders.
- Long term solution would be integration of CNT heaters to the entire apparels of fire fighters and also in devices which can be used in various industries like aerospace, medicine and fitness.

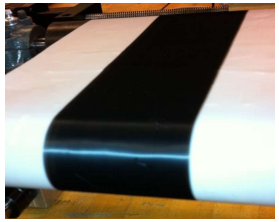
Methodology

a) Synthesis of spinnable CNT arrays by Chemical Vapor Deposition.

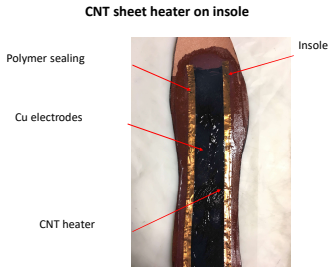
b) CNT sheet drawing



Scalable CNT sheet fabrication



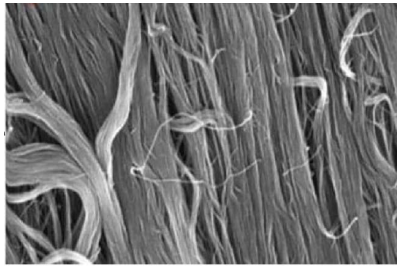
c) CNT sheet heater on insole



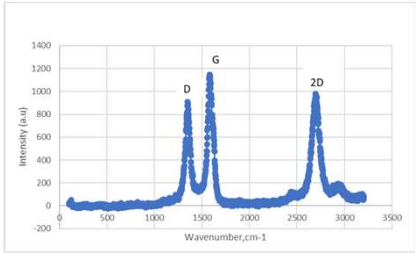
d) CNT heater insole inside the boot for testing

Initial results

- **Scanning Electron Microcopy (SEM)of CNT**



- **Raman Spectroscopy of CNT**



Future Direction

- (a)Optimization of the CNT heater through functionalization and post treatment in order to achieve maximum temperature with minimum powering voltage for high efficiency.
- (b) Fabrication and full characterization of a heatable shoe insole and incorporating it into a pair of boots of first responders with possibilities to regulate and track the temperature.
- (c)In the long run, CNT heaters will be integrated to the entire apparels of fire fighters and also in devices which can be used in various industries like aerospace, medicine and fitness

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Acknowledgment

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Carbon Nanotube Hybrid Fabric Facemask to Filter and Deactivate Virus

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INTRODUCTION

- Conventional facemasks may not adequately protect against the smallest particles which include virus and toxic chemicals in the air [1,2].
- Carbon nanotube (CNT) hybrid fabric is a multifunctional material with light weight, good strength, and it also has antimicrobial property and can improve personal protective equipment (PPE)[3,4].
- CNT fabric has a huge surface/volume ratio and porosity which makes it an excellent choice for filtering applications[5].
- The goal is to develop a new facemask that will be a combination of the filter material used in N95 masks and the CNTH material.
- The face masks will have CNT layers with anti-viral nanoparticles.

OBJECTIVES

- Synthesize CNT fabric pristine and with anti-viral nanoparticles. Clean and functionalize the fabric in acid to remove residual iron catalyst and hydrocarbon by-products.
- Integrate fabric into a facemask.
- Test CNT fabric for nanoparticle release. This will involve mechanical, porosity, and chemical resistance and capture testing.
- Manufacture a prototype facemask with UC DAAP.
- Test the facemask in standard tests with UC Environmental Health Dept.

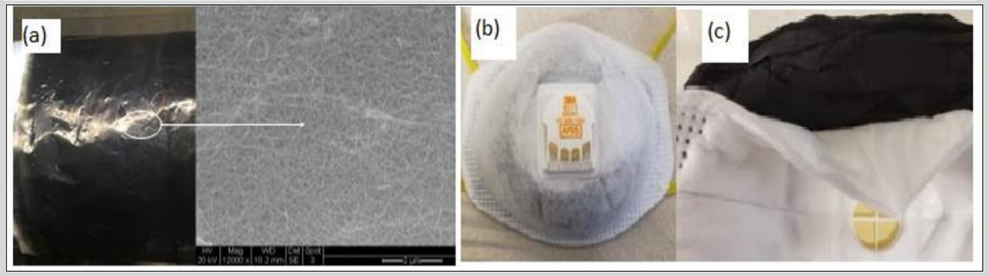
RELEVANCE To NORA

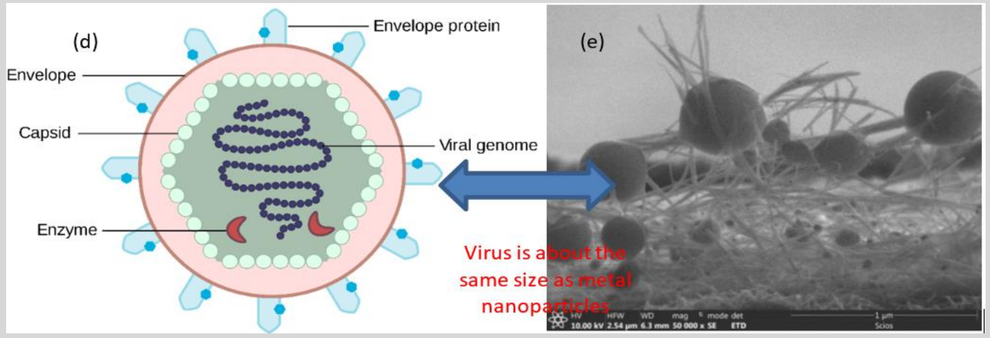
- Daily, public safety workers work in uncontrolled environments that places them in contact with biological, chemical, physical and psychosocial hazards.
- This PRP proposal is to develop a facemask that can reduce the risk of virus and particulate exposure for all NORA personnel.
- Billions of these masks will be needed per year especially with the Centers for Disease Control recommending that all Americans start wearing mask[6].

EXPERIMENTAL DESIGN

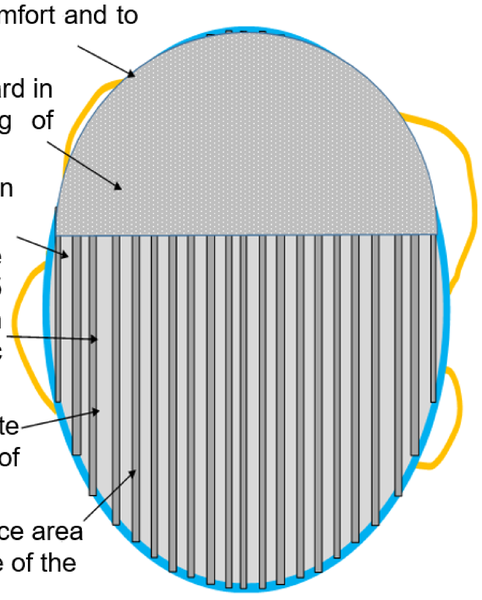
Synthesis of the CNT Hybrid Fabric:

(a) CNT fabric with porosity to capture virus.
(b) N95 respirator facemask with a CNT layer inside.
(c) CNT fabric inside a N95 facemask.
(d) Virus are about the same size as metal NPs.
(e) Metal particles “glue” bundles of CNTs together which increases thermal and electrical conductivity and strength.





1. Silicone seal around perimeter for comfort and to reduce leakage.
2. Top shield directs exhaust air downward in the pleat channels to reduce fogging of eyeglasses.
3. Mask can be cleaned and disinfected in solution and reused.
4. CNT fabric is up to 3x more breathable than conventional N95 meltblown nonwoven fabric and when composited with thin conventional fabric filters virus more efficiently.
5. Ag-Cu-Zn nanoparticles deactivate virus decreasing the chance of retransmission through handling mask.
6. Pleated fabric increases filtering surface area by 2x and increases breathability and life of the mask.



EXPERIMENTAL DESIGN (CONTINUED)

Facemask Performance Assessment:

- A manikin-based system will be used for evaluating the protection efficiencies of various commercially available respiratory masks and the CNTH mask against biological aerosols.
- Statistical analysis will be conducted to analyze the protection efficiencies in different conditions, in different air flow rates and with different mask construction models.
- The protection efficiencies of the CNTH masks will be compared with the available N95 masks in different conditions (i.e. facial movements, with and without sealing, donning/doffing).

FUTURE DIRECTION

- Face masks performance and antimicrobial efficacy will be evaluated after several decontamination methods recommended by CDC.
- Possible degradation of the mask due to use and washing will be tested.
- The findings of this project will be used as the preliminary data for the virus deactivation for a future proposal.

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ACKNOWLEDGEMENTS

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Real-Time Automated Vehicle Crash Detection and Reporting System

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Motivation

- One of the major causes of traffic congestion is vehicular crashes which can cause a halt in traffic operations, particularly, at intersections.
- According to World Health Organization, the number of deaths caused by road traffic crashes is approximately 1.35 million people around the world each year, and between 20 and 50 million suffer people with non-fatal injuries each year due to vehicular crashes.
- Delays in detecting and providing care for those involved in a road traffic crash increase the severity of injuries.
- A faster rescue response has the potential to not only save lives but also result in faster clearing of accidents and lesser congestion.
- **The motivation behind the proposed study is to minimize the response time of the authorities, including first responders and firefighters for restoring the traffic operations after vehicular crashes and in the process save lives**.

Background

- Many cities have low-cost traffic surveillance cameras known as CCTV at road intersections and highways which provide camera feeds for traffic monitoring.
- Recent advances in IoT (Internet of Things) devices and Artificial Intelligence for fast, accurate data processing provide a unique opportunity to develop efficient system for detecting and reporting crashes at traffic intersections.
- Deep and complex neural network architectures has been trained for single and multi-vehicle detection using state-of-the-art object detection frameworks such as Faster R-CNN, MaskRCNN, YOLO and SSD.
- Huang, X. et al. (2020) proposed the use of Convolutional Network architecture for real-time detection, tracking, and near accident detection of road users in traffic video data.
- Foggia, P. et al. (2017) proposed a short-time and long-time analysis of the audio signal to detect both sustained (e.g., tire skidding) and impulsive sounds (e.g., car crash).

Objectives and Project Description

- The main objective of this project is to **develop a low-cost automated vehicle crash reporting video analytics software which can detect and report vehicular crashes at the traffic intersections.**
- The specific aims in the projects includes:
  - Develop a **robust vehicle detection and tracking module** using MaskRCNN, Kalman Filter and Deep Learning.
  - Design and develop an **audio signal processing module** using CNN techniques to detect crash.
  - Design of a crash detection system using the information from the video and audio module.
  - Extensive Testing and Performance Evaluation using metrics such as True Positives, True Negatives, False Positives and False Negatives.
  - Output processed videos for post analysis of the crash.

Software Architecture

- Traffic dataset from Cincinnati area traffic intersections at different locations, different camera angles, and camera zoom levels will be used for testing.

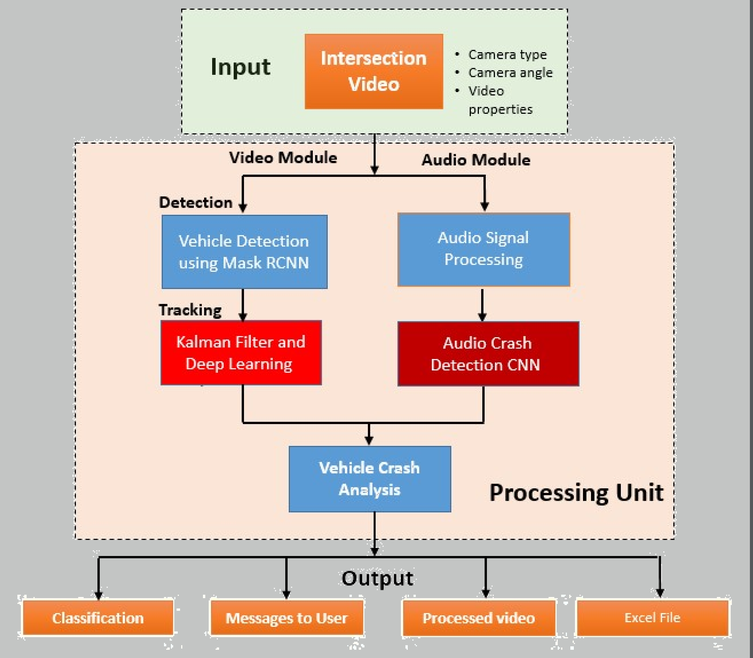

Figure: Flowchart of the Proposed Analytics Software

Expected Results

- The innovative algorithm that combines digital audio signal processing, video and audio Convolutional Neural Network (CNN), and kinematic time-series analysis.
- A GUI based message to the user that a crash has occurred.
- A processed video showing the identified and tracked vehicles.
- The figure below shows one of the frame of the traffic data using MaskRCNN.

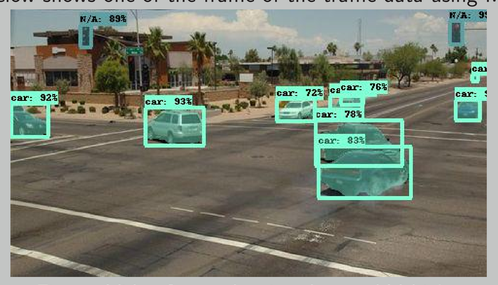

Figure: Video frame showing detected Vehicles

Impact Statement and Future Direction

- The project is applicable to the following **NORA sectors:**
  - Firefighters and first responders.
  - Law Enforcement Agency.
- **Benefits to Society**
  - Quick reporting of a near crash and impact crash scenes to traffic agencies.
  - Ensures that fire fighters and emergency first responders arrive at the scene earlier and better prepared due to access to video at the time dispatch.
  - Post analysis of causes of accidents can be used to improve intersection infrastructure to mitigate some of the causes.
- **Future work of this system may include:**
  - Classifying the scene to emergency and non-emergency scenes.
  - Detection of the kind of vehicle, e.g., trucks, buses, wagons and the likes can be integrated to further generalize the system on any kind of vehicle.
  - Incorporating animals-vehicle crash.
  - Traffic counts and other traffic parameters can be extracted from videos which can be used to understand traffic conditions and improve infrastructure and traffic signal operations.

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- Vehicle Crash Dataset is provided by our collaborator - TEC Engineering.

Home Healthcare Workers' Occupational Exposure to Bacterial and Fungal Bioaerosols: A Pilot Study

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Background

- US population is aging, people are living longer, and health care cost is soaring
- Receiving healthcare in the comfort of one's own home is now the preferred choice
- Consequently, the home healthcare (HHC) industry is booming
  - In 2008, 13.3 million people were employed in private-sector health care
  - Through 2026, healthcare settings job growth is projected to be 18%
  - The number of home healthcare workers (HHCWs) will then increase by 41% meaning more than 4 million additional jobs [1, 2]
  - Unlike other healthcare settings, private homes in which health care is provided are not considered workplaces and therefore no occupational standards, guidelines or regulations exist
- HHCWs face many challenges in their duties including exposure to airborne microbial agents (bioaerosols) such as bacteria and fungi
- Such microbial agents could be associated with adverse respiratory health issues
- Example: Healthcare professionals have a higher prevalence of asthma attacks than non-healthcare workers [3, 4]
- **Gap**: No study has assessed HHCWs' occupational exposure to bioaerosols
- Research is needed to assess the exposure of HHCWs to bioaerosols
- We propose to assess airborne bacterial and fungi in the homes of the clients that HHCWs visit to provide healthcare services.

Objective

Purpose: This pilot study aims to assess the HHCWs' potential exposure to bacterial and fungal bioaerosols in their clients' private homes

Specific aim 1: Characterize the bacterial and fungal community profiles in the homes that HHCWs visit, by quantifying bacterial and fungal DNA with real-time polymerase chain reaction (qPCR) and by using next-generation sequencing (NGS) to establish the metagenomic profile of the homes based on the collected air and surface samples.

Specific aim 2: Compare the microscopy and the InstaScope™ methods in detecting bacteria and fungi in the private homes visited by HHCWs.

Hypothesis**:** There is a positive linear relationship between the microscopy counting and the InstaScope™ methods.

Significance

- Fill the knowledge gap on HHCWs' exposure to bacterial and fungal bioaerosols
- To our knowledge, this is the first study to investigate bacterial and fungal bioaerosol exposure in HHCWs
- The study objectives align with NIOSH National Occupational Research Agenda
- Findings will contribute to future studies, standards and/or regulations to protect HHCWs

Study population

Inclusion criteria: Subjects are home healthcare workers who must be:

- Adults employed as HHCW in the Kentucky-Indiana-Ohio tristate area
- In HHC for at least one year and HHC is their only job at the time of data collection
- Age: 18 years old or older
- In overall good physical health
- With no respiratory disease prior to the current job

Methods and activities

Study design

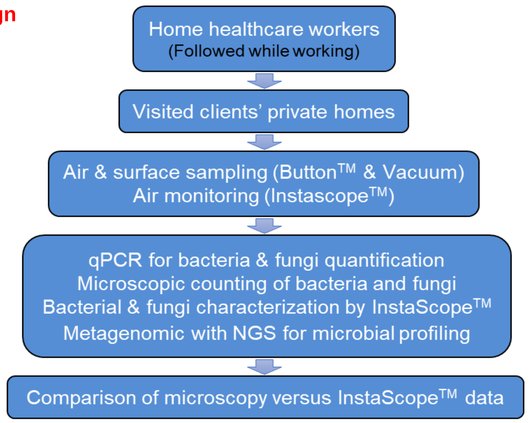

Figure1: Bacteria and fungi assessment in homes visited by home healthcare workers during their caregiving duty.

Recruitment

- Advertise the study to targeted home healthcare agencies in the area
- Contact, screen, recruit, and enroll volunteer participants
- Sign informed consent as per the Institutional Review Board (IRB) approval
- Obtain home access permission from homeowners/clients
- Schedule a one shift-long sampling session with each participant

Sampling and data collection

- Sample indoor surfaces and air using vacuum and Button aerosol samplers
- Monitor fungal spore concentration and distribution using the InstaScope™

https://www.skcinc.com/catalog

Button Aerosol Sampler

Sampling vacuum

https://www.instascope.co/

InstaScope

Figure 2: Devices and instruments to be used for data collection

Sample analysis

- qPCR with universal primer to quantify DNA copy of microbial agents
- InstaScope™ generates data reports in real-time
- NGS using Illumina MiSeq with the internal transcribed spacer (ITS) and 16S rRNA amplicons to evaluate the diversity and abundance of fungi and bacteria

Metagenomic and statistical analysis

- QIIME, R software, Bioconductor and "vegan" package for data analysis
- Wilcoxon test to compare single vs. multiple home visit(s) groups
- α and β diversity for taxa diversity and relative abundance
- Cluster analysis and PCA for microbial communities overlaps in homes

Expected results

- Visited homes' bacterial and fungal profiles will be established
- Positive linear relationship will be established between the microscopy and the WIBS-based InstaScope™ methods

Limitations and challenges

- Cross sectional design and small sample size (20 subjects to be enrolled) will limit the generalization of our findings
- Confounders: exposure from HHCWs own homes, traffic & ambient air, etc.
- Potential for selection bias: Reliance on convenient sample of subjects
- Major challenges: Difficulty recruiting HHCWs and hesitancy of their clients

Impact and Future direction

Impact statement: We are using cutting-edge technologies (metagenomics, NGS and InstaScope) to characterize for the first time the microbial profile in HHCWs' workplaces which are their clients' private homes. If concerning findings, we will provide appropriate materials on indoor air quality to HHCWs participants and the home occupants through the UC Community Engagement Core (CEG). Our findings will lead to future longitudinal studies which outcomes will help policymakers make informed and sound decisions when establishing guidelines, standards or regulations to protect HHCWs

Future direction: This pilot study will pave the way for a further longitudinal study to investigate actual personal exposures to bioaerosols, as well as their association with respiratory health effects among HHCWs

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