
# RESIDENTIAL RADON SAMPLING IN PUERTO RICO

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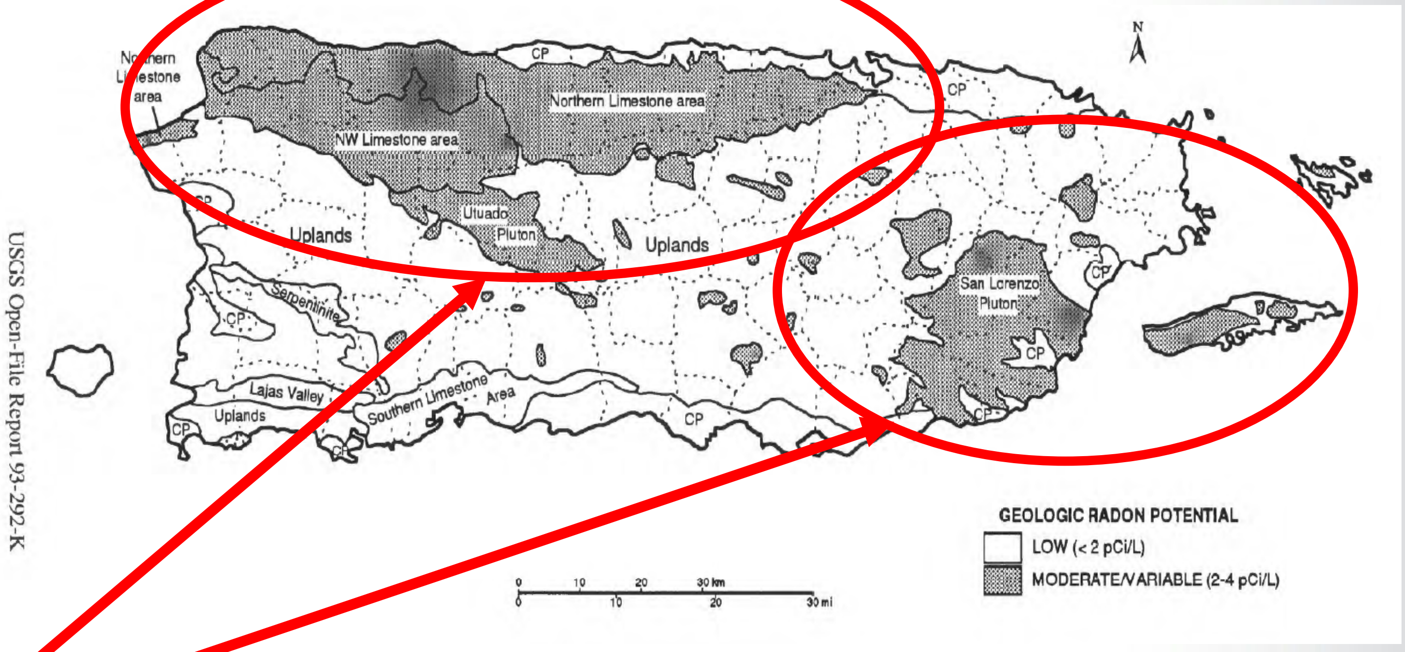
# OUTLINE

- The Issue
- Radon Infrastructure in Puerto Rico
- Study Objectives
- Research Approach
- Materials and Methods
- Results
- Further Steps
- Questions

# The Issue

- Very limited data exist on indoor radon in Puerto Rico
- No baseline radon data exist for Puerto Rico
- USGS geologic study in 1993-95 concluded that radon problems exist~~s~~ on the island
- This USGS 1995 map shows grey areas that have higher radon potential



# The Issue (cont.)

- Karst geology, porous soils and increasing use of AC exacerbate radon problem
- Radon monitors that are commonly used on the mainland may not be suitable for tropics

*AC units become more common on the island*

# Radon Infrastructure in Puerto Rico

- No radon professionals registered at project onset

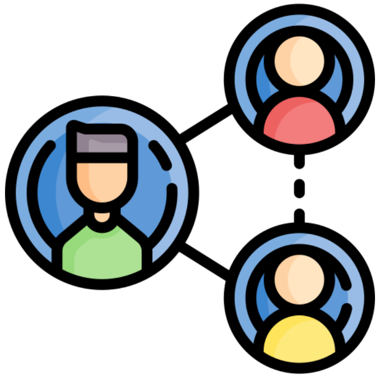
- Currently, for a population of 3.3 M and an area of 5,325 square miles, the island has:
  - Three NRPP certified Measurement Professionals in 2023 (including newly certified member of our team)

  - No NRPP certified Mitigation Professionals

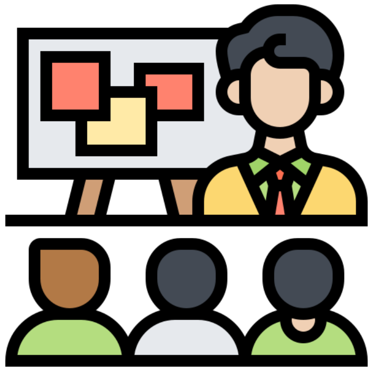
# Study Objectives:

- To safeguard communities of Puerto Rico from radon hazards through:
  - sampling of single-family homes
  - testing with new low-cost instruments
  - training
  - capacity building
  - remedial actions

# Research Approach



Connect with the community



Educate

Deploy & Measure

Quality Assurance

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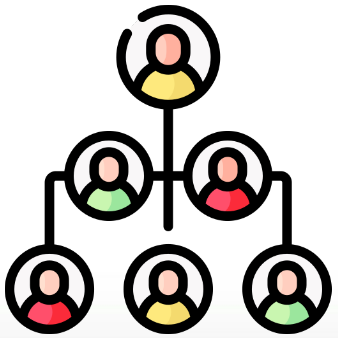
EPA & UPRM agree to sample Radon in Puerto Rico Northwest



UPRM assembled a student team to work together using local knowledge to improve project execution

# Research Approach

- Outreach to communities and municipalities
- Sign-up of volunteer homes

# Research Approach

- Media events
- Social media outreach
- Presentations

## La EPA y la UPR de Mayagüez lideran proyecto para medir niveles de radón en Puerto Rico

La agencia federal y un equipo de ingeniería del recinto universitario encabezan el esfuerzo que proporcionará un mapa de datos mostrando el alcance de este gas radiactivo, inodoro, invisible y cancerígeno

sábado, 3 de julio de 2021 - 11:40 p.m. Por Gerardo E. Alvarado León

Nota de archivo: este contenido fue publicado hace más de 30 días.




Los monitores electrónicos de radón se instalan en los hogares por una semana. En la foto, el profesor Pedro Tarafa Vélez. (David Villafañe Ramos)


# Two Stage Research Approach:
# I. Scoping Rn Sampling

Identify cases of interest

Quality assurance

Contact & set appointments

Determine Radon level

Deploy up to 5 teams at a time

Wait 1 week for study to complete


**Sampling Devices**

# Two Stage Research Approach:
# I. Scoping Rn Sampling (cont.)

- Calibration, spiking, pre-deployment checks of monitors and radiation meters

- Training of university teams

# Spiking and Performance of Consumer Grade Monitors

- Consumer grade Corentium Home monitors were spiked at NRPP certified KSU Radon Chamber
- Reported Individual Relative Errors (IREs) below 15% for most spiked devices
- Study used data only from devices with IRE < 25%

## Radon Chamber
### Kansas State University

KSU Radon Chamber NRPP Certification ID Number SC-1006

Date: 10/7/2022

Dr. Oleg Povetko
EPA Region II
2890 Woodbridge Ave Edison NJ 08837
210.323.5590
Povetko.oleg@epa.gov

These are the results of the spiking that we performed on the device(s) listed below:

| Device Serial # | Start Date | Start Time | Stop Date | Stop Time | Device Value * | IRE |
|---|---|---|---|---|---|---|
| CH2302104611 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.2 | 5.2% |
| CH2302088701 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.5 | 2.2% |
| CH 2302104666 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.1 | 4.8% |
| CH 2302105207 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.5 | 2.2% |
| CH 2302104689 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.4 | 1.7% |
| CH 2302105248 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.9 | 0.4% |
| CH 2302103959 | 9/30/22 | 1230 | 10/7/22 | 1230 | 21.8 | 5.2% |
| CH 2302103893 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.5 | 2.2% |
| CH 2302088972 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.3 | 5.7% |
| CH 2302104670 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.0 | 8.7% |
| CH 2302105326 | 9/30/22 | 1230 | 10/7/22 | 1230 | ERROR | N/A |
| CH 2302104673 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.5 | 6.5% |
| CH 2302104684 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.1 | 3.9% |
| CH 2302105260 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.7 | 7.4% |
| CH 2302103233 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.2 | 9.6% |
| CH 2302105258 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.1 | 9.1% |
| CH 2302105259 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.3 | 1.3% |
| CH 2302103826 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.1 | 3.9% |
| CH 2302104700 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.0 | 0.0% |
| CH 2302104695 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.8 | 3.5% |

**Chamber Target Value:23.0 pCi/L**

**These devices were spiked in our chamber at an average relative humidity of avg/rh 23 %.**
**These devices were spiked in our chamber at a chamber temperature of 73 °f.**
**This chamber is at an elevation of approximately 1020 feet.**

The additional information below is provided as a service for our customers who have furnished KSU Radon Chamber with the customer's measured values for the above devices. This equation calculates the difference between our chamber value and the customer's measured value and is called the percent error. It is calculated as follows:

$$\% \text{ Error} = \frac{\text{Measured Value} - \text{Chamber Value}}{\text{Chamber Value}} * 100$$

**Measured Value:** pCi/L **Chamber Value:** pCi/L **Error:**

Thank you for your patronage. If we can be of further help, please email us at radonchamber@ksu.edu or call us at (785-532-4992

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|---|---|---|---|---|---|---|
| CH2302103894 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.6 | 2.6% |
| CH2302104687 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.8 | 7.8% |
| CH2302104680 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.2 | 5.2% |
| CH2302103881 | 9/30/22 | 1230 | 10/7/22 | 1230 | ERROR | n/a |
| CH2302104603 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.1 | 4.8% |
| CH2302103174 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.2 | 0.9% |
| CH2302104662 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.1 | 3.9% |
| CH2302105257 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.6 | 11.3% |
| CH2302088706 | 9/30/22 | 1230 | 10/7/22 | 1230 | 26.4 | 14.8% |
| CH2302104610 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.9 | 3.9% |
| CH2302104704 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.9 | 0.4% |
| CH2302105254 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.8 | 7.8% |
| CH2302103937 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.6 | 2.6% |
| CH2302105249 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.0 | 0.0% |
| CH2302105323 | 9/30/22 | 1230 | 10/7/22 | 1230 | NOT EXPOSED | n/a |
| CH2302104692 | 9/30/22 | 1230 | 10/7/22 | 1230 | 22.9 | 0.4% |
| CH2302104710 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.9 | 3.9% |
| CH2302104664 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.2 | 9.6% |
| CH2302105206 | 9/30/22 | 1230 | 10/7/22 | 1230 | 24.2 | 5.2% |
| CH2302104694 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.7 | 3.0% |
| CH2302104649 | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.6 | 11.3% |

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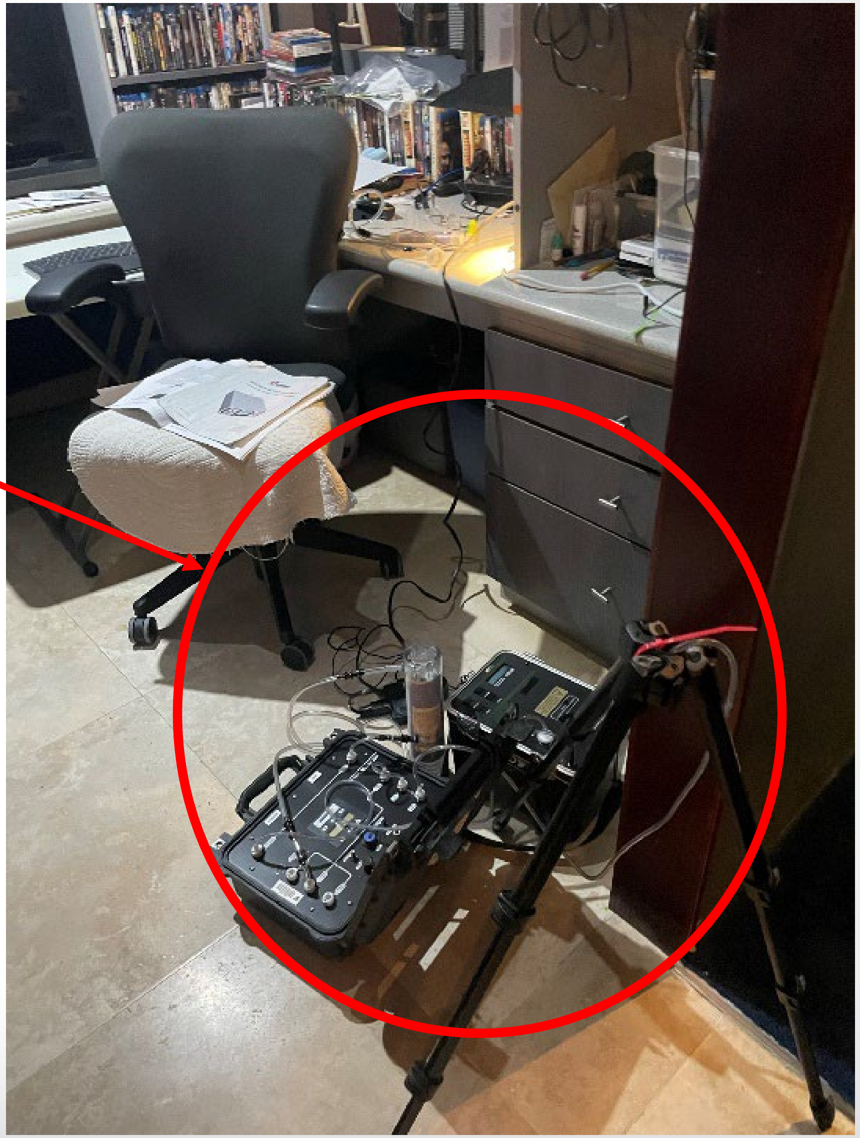
**Measured Value:** pCi/L **Chamber Value:** pCi/L **Error:**

# Two Stage Research Approach:
# 1. Scoping (cont.)

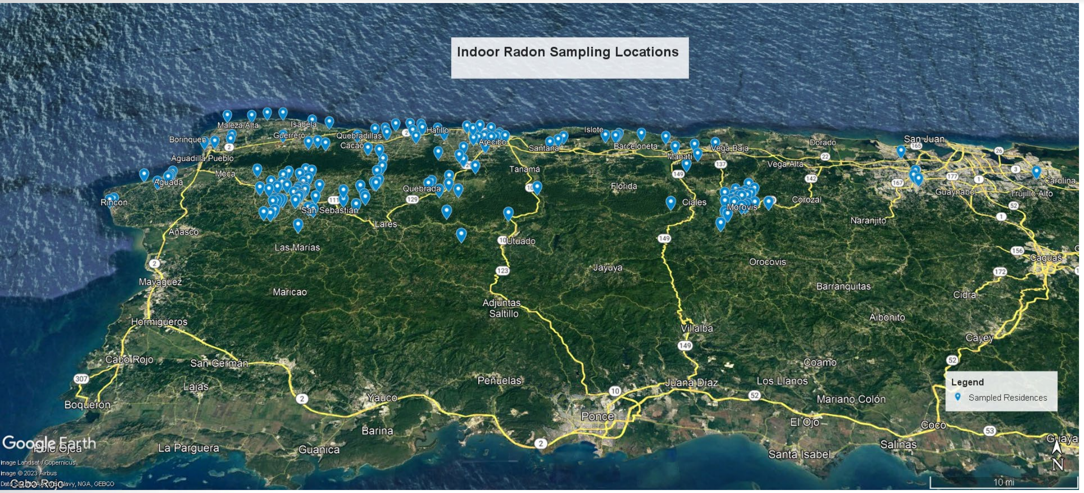
- Scoping survey of homes by student teams using consumer grade low-end e-monitors
  - data collected provided seven-day integrated radon concentrations
- Using dedicated phone app, Data Collectors directly uploaded to EPA cloud database from field locations:
  - Radon concentration level
  - Geolocations
  - Photos of instruments' SNs and display screens
  - Comments and observations
- Identification of potentially "high" homes


# Two Stage Research Approach:
# 2. Confirmatory Sampling

- Confirmatory sampling by radon professionals of potentially “high” homes using high-end professional instruments



# Preliminary Results




173 homes sampled by university teams and EPA staff

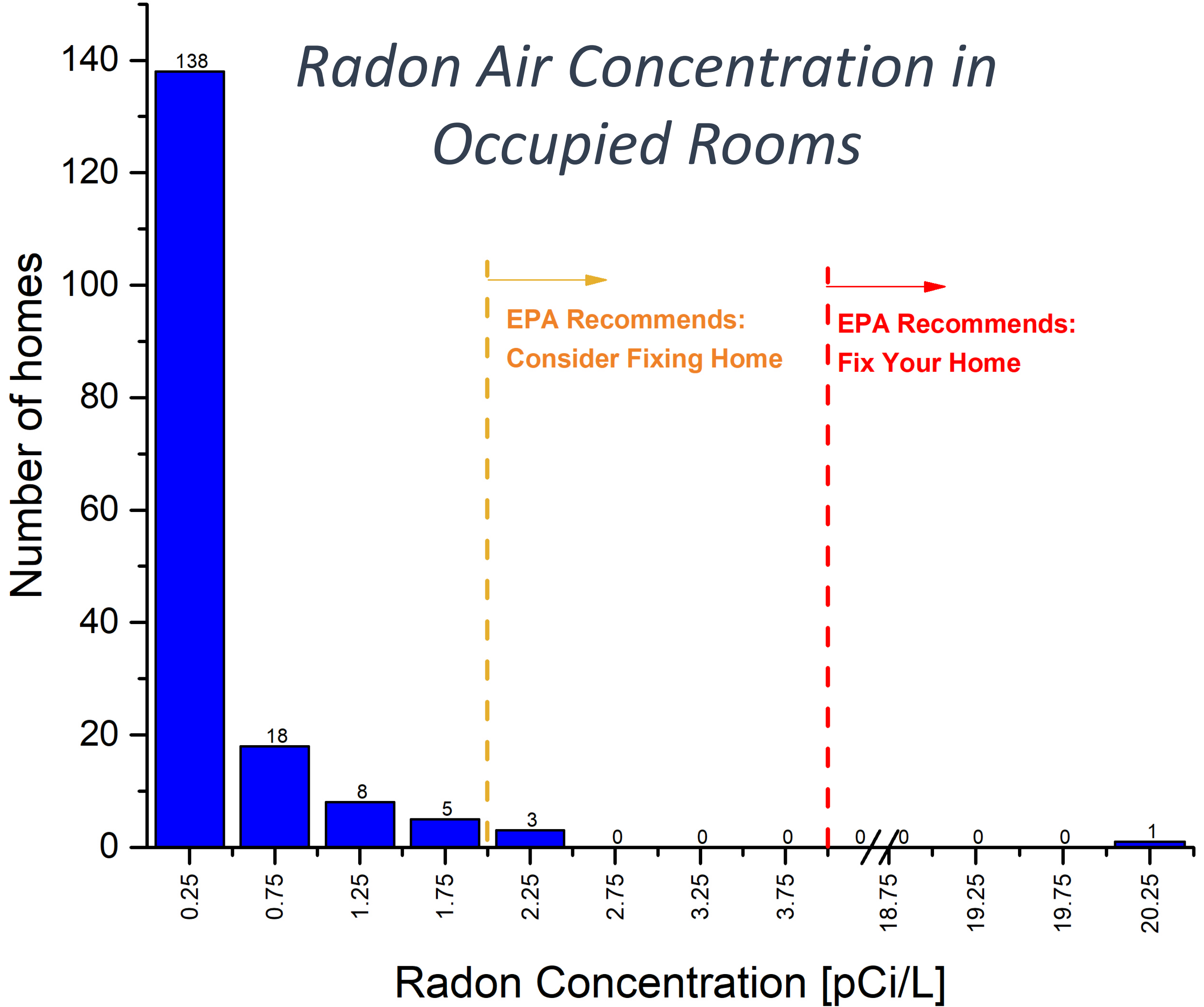
Sampling locations above are approximate; presented only for illustration of  extension of sampled area


One team member became NRPP certified Radon Measurement Professional

NRPP Certified Radon Mitigation Specialist conducted pre-mitigation studies of several homes

## Preliminary Results – Data Collected by E-Monitors

- Occupied rooms in four homes confirmed above 2 pCi/L, EPA level for considering mitigation
- Occupied rooms in one home confirmed above EPA Action Level of 4 pCi/L
- Occupied rooms in one home confirmed above 20 pCi/L (home uses central AC)
- Non-living ground level rooms in four homes sampled between 4 and up to 280 pCi/L
- Data is log-normally distributed



# Preliminary Results (cont.)

- Several local companies expressed interest in mitigation work

*Identified radon gas entry point in home with >20 pCi/L levels*

***Performance of consumer grade monitors:***

*-they gradually fail*

*-some begin displaying ERROR or 0.0*

*-some displays fail but monitors remain operational*

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| CH 2302103233 | [illegible] | 1230 | 10/7/22 | 1230 | 25.2 | 9.6% |
| CH 230210525[illegible] | 9/30/22 | 1230 | 10/7/22 | 1230 | 25.1 | 9.1% |
| [illegible]2105259 | 9/30/22 | 1230 | 10/7/22 | 1230 | 23.3 | 1.3% |
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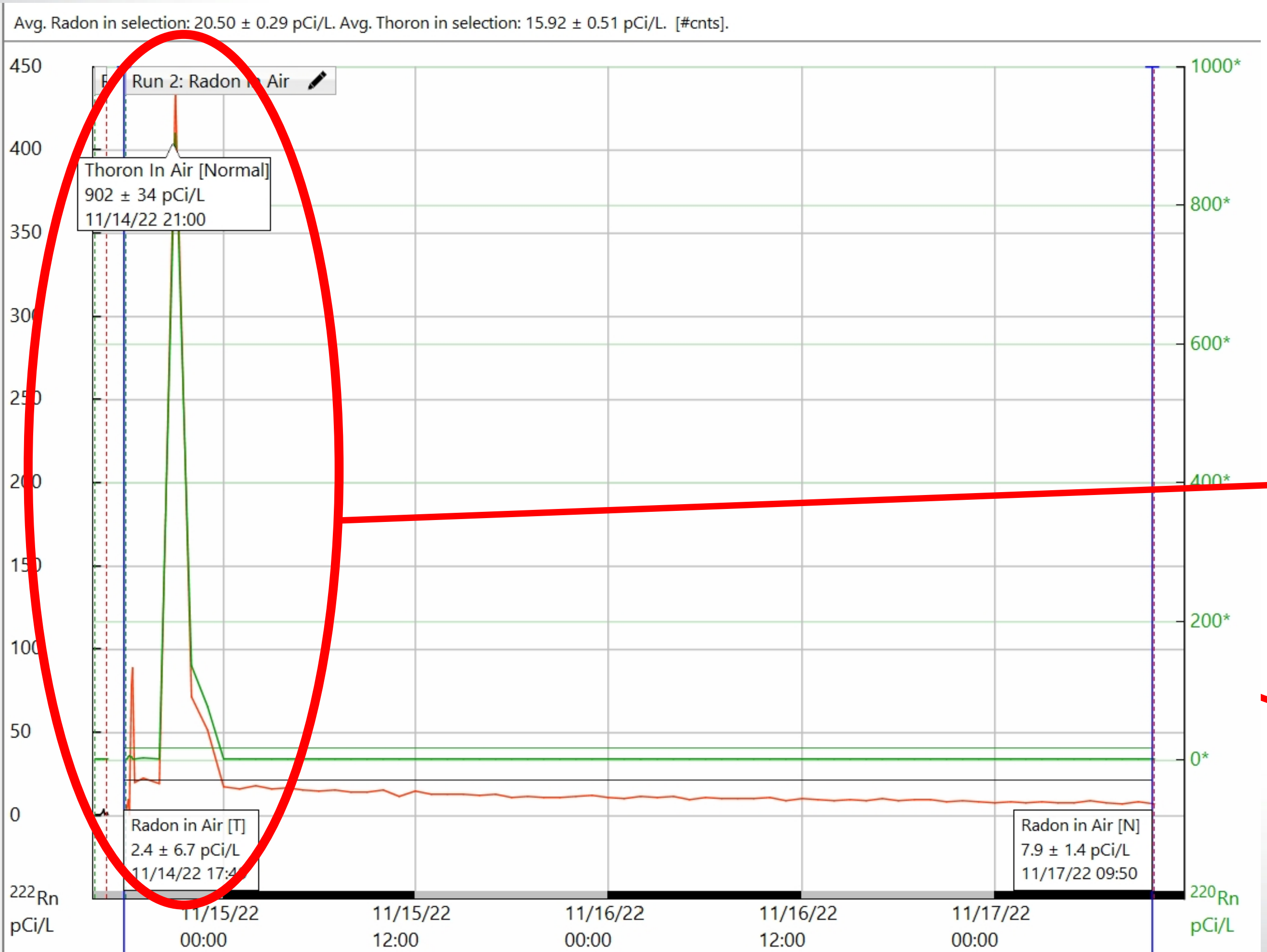
# Preliminary Results-Observations, Lessons Learned

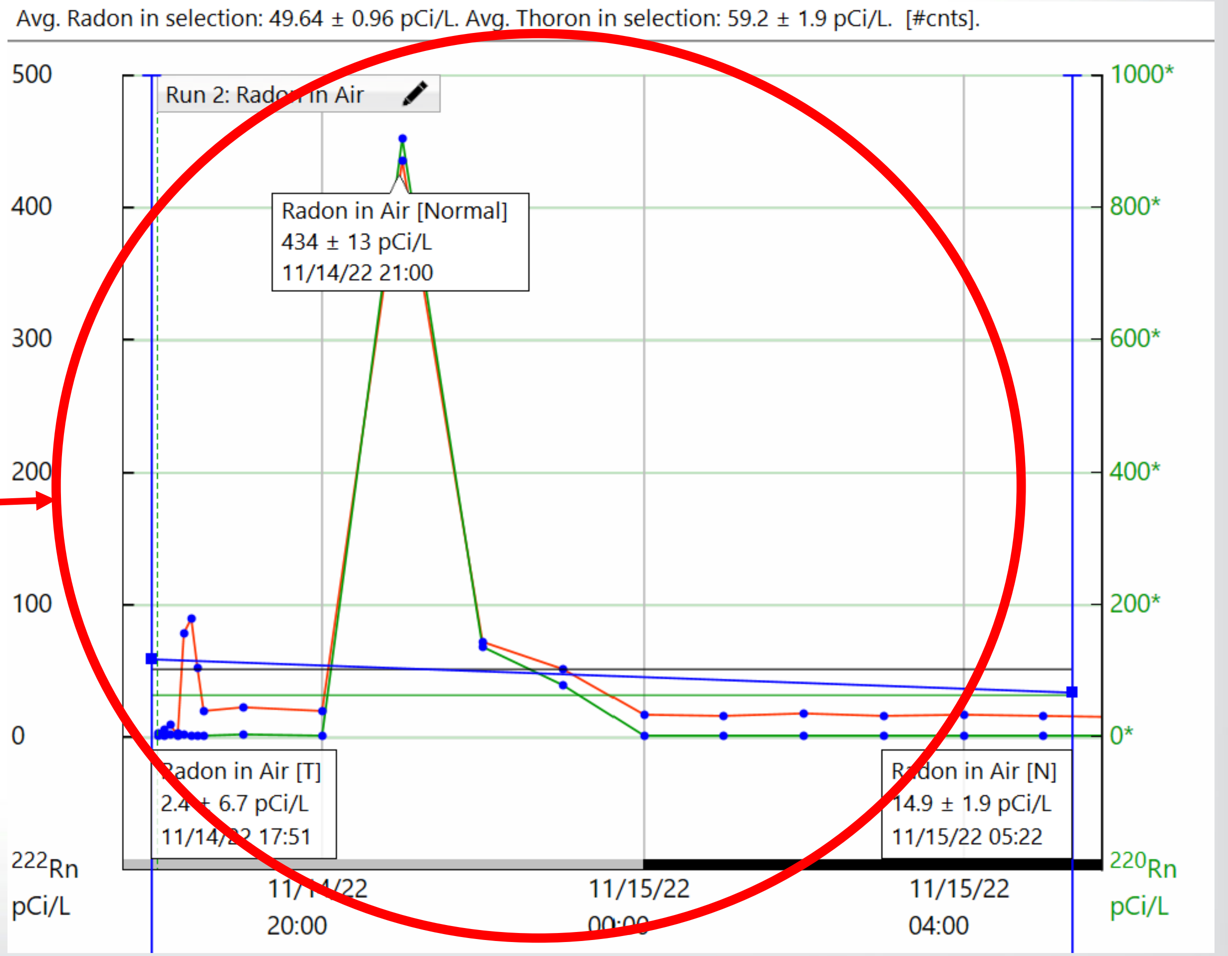
- Jalousie/louvered windows are extensively used on the island
- They are not air-tight even when shutters closed
- Most of sampled homes lacked basements or crawl spaces
- Extensive use of jalousie/louvered windows and lack of basements appear
    - to allow sufficient ventilation to minimize the risk of elevated radon in occupied rooms
    - to prevent radon accumulation under occupied rooms
- Potential transition to central AC without introduction of outdoor air and to air-tight building construction will likely cause elevated radon levels
- E-PERM® electrets should be processed and electret readers used exclusively in low dust air-controlled laboratory
- Data Collectors require additional on-site oversight and training

# Preliminary Results-Radon Spikes

-Spikes of radon (max ~434 pCi/L ) and thoron (max ~902 pCi/L) were observed in home within 6-hour period

-Spikes coincided with two seismic events recorded within one hour after spikes 34 and 70 km away



# Preliminary Results - Radon Flow Computational Fluid Dynamics (CFD) Modeling of Room - Motivation, Model and Workflow

**MOTIVATION:**

- Several sampled houses have high levels of radon and may need mitigation to protect the health of their inhabitants, according to the first results of the study
- 1 in 15 homes in continental U.S. have high radon levels and should consider mitigation

**MODEL:**

- A mobile vacuum filtering robot system that will sweep across the floor and absorb radon into an activated charcoal bed

**WORKFLOW:**

- **Data Acquisition:** The first step is to determine the geometry (physical domain) of the simulation and gather all parameters, initial conditions, and boundary conditions necessary to perform the study
- **Mesh Generation:** This step discretizes the physical domain into various points or elements and generates a subdomain (computational domain) for numerical calculations
- **Simulation:** This step solves for the given fluid flow at each point or element in the computational domain. These are the Heat Equation for temperature, the Navier-Stokes equations for fluid flow and Advection-Diffusion equation for Species Transport.
- **Post-Processing:** Simulation results are analyzed a visual representation may be generated

# Preliminary Results – CFD Room Model

## GOVERNING EQUATIONS

- **Advection Diffusion Equation (Species Transport)**
- $\partial C/\partial t = D\nabla^2 C - \vec{\nabla}\cdot(C\vec{\boldsymbol{V}}) - \lambda C - KC$
- $\lambda$ = Radon Decay Constant
- $K$= Activated Charcoal Filter Radon Removal Rate
- **Incompressible Navier-Stokes Equations (Fluid Flow)**
- $\rho(\partial\vec{\boldsymbol{V}}\partial t + \vec{\boldsymbol{V}}\cdot\nabla\vec{\boldsymbol{V}}) = \mu\nabla^2\vec{\boldsymbol{V}} - \nabla P$
- $\vec{\boldsymbol{\nabla}}\cdot\vec{V} = 0$

## BOUNDARY CONDITINS

**Concentration flux through floor:**

$J_{Rn} = -D_{Rn\rightarrow Air}\partial C(x,y,0,t)/\partial z$

**No concentration flux through walls and ceiling:**

$\partial C(0,y,z,t)/\partial x = \partial C(L,y,z,t)/\partial x = \partial C(x,0,z,t)/\partial y =$
$= \partial C(x,W,z,t)/\partial y = \partial C(x,y,H,t)/\partial z = 0$

**Initial Conditions:**

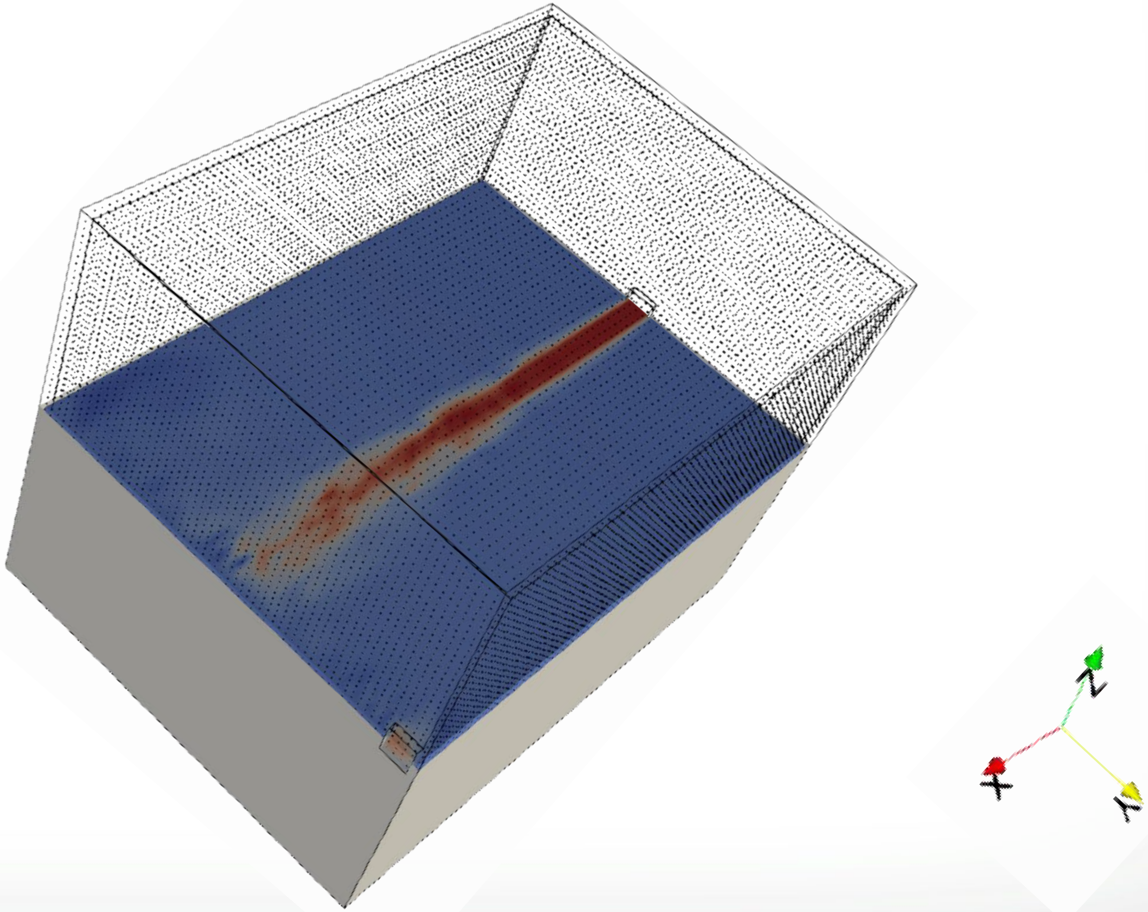
$C(x,y,z,0) = C_0$

$\vec{V}_{inlet} = u\,\vec{i} + 0\vec{j} + 0\vec{k} = u_0$

**No slip Condition:**

$\vec{V}|_{surfaces} = 0$

# Preliminary Results - Generated Mesh and Initial Radon Flow




*-3-D Model of room*

*-Room floor (dark blue)*

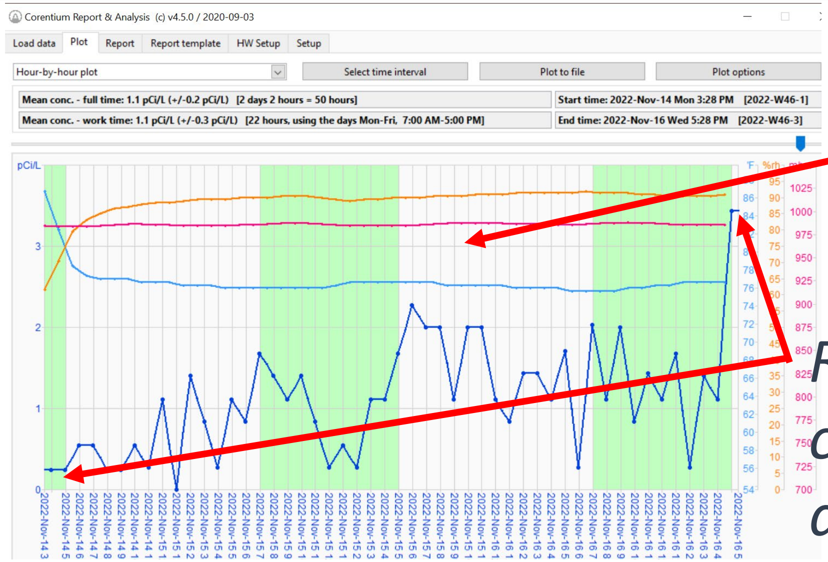
*-Radon flux (dark red color)*

## Preliminary Results - CFD for Radon Distribution and Mitigation

- Distribution of radon (and its progeny) in air can be studied and predicted by employing CFD techniques
- Factors that affect radon distribution and mitigation such as temperature, pressure differentials, and humidity can be incorporated into these models
- Installation and operational costs can be reduced by optimizing a systems design and/or efficiency through simulation
- In conclusion, CFD can be a valuable tool to maintain and develop healthy indoor air quality

# Next Steps

- Sampling of earthquake impacted areas and island's southeast area with higher radon potential
- Comparison of long-term (60-90 days) with short-term (2-7 days) sampling
- Compare performance of low-cost portable radon sensors with high end systems that control measurement environment
- Study for design and construction of island-specific mitigation systems




*Weather data*

*Radon concentration during 48 hr sampling gradually increases to 3.5 pCi/L*

*Pre-mitigation study of "high" home blueprints*

# DISCLAIMER

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# QUESTIONS?


Radon Testing & Mitigation
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Mayaguez