This story is based on the FRESH study, a community-engaged project led by the University of Kentucky College of Nursing and funded by the National Institute of Environmental Health Sciences (R01ES021502). FRESH stands for Freedom from Radon Exposure and Smoking in the Home.

Radon and tobacco smoke exposure are the two leading causes of lung cancer. More than 220,000 new cases of lung cancer are diagnosed each year in the United States and Kentucky leads the nation with the largest proportion of new cases each year. People exposed to radon and tobacco smoke are 10 times more likely to be diagnosed with lung cancer than those who are not exposed to both. So, while radon is dangerous to everyone, it is even more dangerous to people who also inhale tobacco smoke.

Our story introduces readers to the combined risks of radon and tobacco smoke through the experiences of a small family with an asthmatic daughter. We also emphasize the importance of geology in understanding the origin and movement of radon, a completely natural radioactive gas, into buildings.

The good news is that many cases of lung cancer can be prevented by simply eliminating tobacco smoke and radon inside homes and other buildings. During the FRESH study, we found that offering free radon and tobacco smoke test kits in healthcare settings and providing personalized radon test results to each homeowner increases radon testing and mitigation. Our fictional family’s behavior and actions as they seek to reduce radon levels within their home provides a general model that you can adapt and follow in your own home.

Because radon gas cannot be seen, smelled, or tasted, it is essential to test your home and know your level.
5 METERS BELOW THE SURFACE, UNDISCLOSED LOCATION, IN KENTUCKY

AH, YES! SECTOR 3884 IS RICH WITH URYUM, THORIUM, AND RADIIUM! THIS WILL GENERATE A LOT OF RADON! THOSE TROUBLE-SOME HUMANS WON’T KNOW WHAT HIT THEM... [1]

LEX, I’D LIKE TO TAKE A CLOSER LOOK AT SECTOR 3884.

ABSOLUTELY, DR. RAY-DON! PLEASE STANDBY...

ZOOM IN HERED... THEY’RE GETTING READY TO DECAY! [2]

I DON’T FEEL SO GOOD...

“ THERE THEY GO!”

THEY NEED TO GET TO THE SURFACE AND IN THE HOME WITHIN THE NEXT FEW DAYS SO THOSE PESKY HUMANS WILL BREATHE THEM IN BEFORE THEY DECAY AGAIN.

[1] Radon is a naturally occurring radioactive gas that is produced during the breakdown of uranium, thorium, and radium within soil, rocks, and water (NCEH, 2020).

WHAT ARE YOU LOOKING AT? [2]

WE MUST WATCH THEIR PROGRESS.

MWAHA HAHAHA HAHA

SUCCESS! RADON GAS ENTERED THEIR HOME! THEY CAN'T ESCAPE!

[1] Chemical elements make up everything around us. Most are stable (they do not change) and happy, while others are unstable and change over time. These unstable elements, like uranium, thorium, and radium, are radioactive. Tiny particles and energy ("radiation") fly out of radioactive elements, causing them to change into a different element with different radioactive properties (AFSDE, 2012).

[2] Radon levels naturally vary depending on where you live (geographic area) and the local geology. In Kentucky, you can check the estimated radon values for your area at https://www.uky.edu/KGS/radon/ (KGS, 2020).
LET'S HOOK 'EM, LADIES AND GENTLEMEN...

THESE ORDERS MUST SHIP TODAY! THE NEW ADVERTISING CAMPAIGN STARTS NEXT WEEK...

HOW MUCH LONGER UNTIL THEY'RE READY TO GO?

"IT'S TIME WE HOOKED A NEW GENERATION OF SMOKERS..."
HAAAA! HAAAA! HAAAA!

WHOOAAA! IT’S HAPPENING!

HURRAY! WE MADE IT! YAY!

LET ME AT ‘EM!

MAKE IT STOP!

WHERE ARE WE GOING?

IS THAT A GREY BAND?

YEP! LET’S SAY ‘HI’!!

[5] Once radon is produced, the gas moves through the soil, into the air and/or dissolves into water (US EPA, 2016a).
[6] Radon enters all buildings, regardless of age or construction material, through openings and cracks in foundations, floors, walls, windows or around pipes (US EPA, 2016a).
Hey guys—look who it is! 177

Welcome to the party! Care to join us?

Don’t mind if I do!

1...2...3! Blow them out!

Meh ha ha ha!

Does someone need her inhaler?

It looks like your inhaler is almost empty. I’ll go to the pharmacy first thing tomorrow,

[7] Radon is a known cause of human lung cancer. There is no safe level of radon.
THE NEXT MORNING...

HELLO! I AM SUSAN SMART FROM THE UNIVERSITY. WHILE YOU'RE WAITING, CAN I TELL YOU ABOUT OUR RESEARCH ON RADON AND TOBACCO SMOKE IN HOMES? [9]

SURE! I'VE NEVER HEARD OF RADON...

RADON IS A GAS THAT YOU CAN'T SEE, SMELL, OR TASTE. AFTER SMOKING, RADON IS THE 2ND LEADING CAUSE OF LUNG CANCER. [9]

I DIDN'T KNOW RADON COULD HURT MY FAMILY!

DO YOU WANT TO LEARN MORE ABOUT OUR STUDY?

SURE!

MEET TEST AND KIT TEST Will MEASURE RADON WHILE KIT WILL SEE HOW MUCH TOBACCO SMOKE IS IN YOUR HOME. [10]

COOL! ARE WE GOING TO TAKE THEM HOME?

WE ARE!

DON'T OPEN THEM 'TIL YOU'RE HOME AND READY TO TEST!

[9] Tobacco smoke and radon are the 2 leading causes of lung cancer, and exposure to both heightens the likelihood of getting the disease (Tahm et al., 2019).

[10] The only way to know if you are being exposed to radon is to test for the gas using commercially available test kits or handheld electronic monitors (US EPA, 2016a).

[10] Passive nicotine samplers are typically only available through research studies and are not commercially available.
LOOK, THEY'RE HOME! \[11\]

WELL, WELL, WELL, WHO DO WE HAVE HERE?

THEY LOOK FUNNY!

JUST IN TIME TO HELP CLEAN UP.

DID YOU GET MORE GIFTS?

I WILL HELP AFTER I PUT AWAY THE GROCERIES.

WE MET A RESEARCHER AT THE PHARMACY WHO'S DOING RESEARCH ABOUT RADON AND TOBACCO SMOKE IN THE HOME. THIS IS TEST KIT THEY'RE GOING TO HELP US.

UH OH... THIS DOESN'T SOUND GOOD!

EVERYTHING IS FINE HERE... NOTHING'S WRONG WITH THE HOUSE. \[12\]

HA! LOOK WHO'S IN THE DRAWER!

YOU TWO WON'T BE DOING ANYTHING NOW!

WILL THEY FORGET ABOUT US?

NO, WE JUST NEED TO BE PATIENT.

\[11\] Radon absorbs onto dust and other particles such as tobacco smoke in buildings. This increases our risk of exposure (ATSDR, 2012).

\[12\] *Anyone* can be exposed to radon – there is no safe level of radon exposure.
DO YOU SMELL THAT? THAT SMOKY ODOR?

I DON’T SMELL ANYTHING!

AHHH... THIS IS THE LIFE!

OH, IS THERE SOMETHING?

I WANNA WATCH CARTOONS!

I WOULDN’T TELL YOU THIS, BUT SMOKE CAN BE ESPECIALLY DANGEROUS IF THERE IS RADON IN THE HOUSE. HONEY, I THINK WE SHOULD USE THOSE KITS IN THE DRAWER. [13]

HERE—SMELL THIS... WE SHOULDN’T HAVE ASKED PEOPLE TO SMOKE OUTSIDE AT TINA’S BIRTHDAY PARTY, THE TOBACCO SMOKE IS PROBABLY IRRITATING TINA’S ASTHMA.

I TOTALLY FORGOT ABOUT THEM! GREAT IDEA!

I FORGOT YOU TWO WERE IN HERE... [14]

ARE YOU TWO READY TO GET TO WORK?

I DON’T LIKE THE LOOKS OF THIS. [15]

WE GOT THIS.

[14] The short-term radon test kits will not expire as long as the plastic bag is not opened (First Alert, 2020).
[15] When deploying test kits within the home, pick a regularly used room. Place the kit on a surface at least 20 inches above the floor, where it will not be disturbed (US EPA, 2016a). Learn more at: https://standards.aarst.org/MAH-2019/index.html.
WHAT ARE YOU TWO DOING ANYWAY? [BE]

AM I SUPPOSED TO BE SCARED?

MUST... RESIST... THE FORCE...!

NOOOOO!

THIS IS NOT COOL!

I DON'T LIKE THIS GAME ANYMORE!

HOW IS SHE SO STRONG?!

2 DAYS LATER...

WHEN ARE THEY LEAVING?

WHATEVER YOU DO, DON'T GO NEAR THEM!

WE'RE READY TO BE PACKAGED AND SENT TO THE LAB! [[7]]

I'M HAVING A ROTTEN DAY!

NOT SOON ENOUGH!

TEST IS GOING TO A LAB IN TEXAS, SO WE KNOW HOW MUCH RADON IS IN OUR HOME. IT WILL GO TO MARYLAND TO SEE HOW MUCH SECONDHAND SMOKE WE HAVE. [18]

GOOD RIDDANCE!

BYE, TEST! BYE, KIT! HAVE A SAFE TRIP!

[16] When testing for radon in your home, do not place the kit in hallways or closets, rooms with high humidity (kitchens, bathrooms), or near a draft (US EPA, 2016a).

[17] To learn more about selecting the best location to monitor tobacco exposure within your home, check out: http://www.shmonitoring.org/ (JHU, 2020).

[18] Exposure to secondhand smoke can be determined by measuring concentrations of air nicotine and other particles that can penetrate deep into the lungs (JHU, 2020).
The radioactivity of radon is measured in “picocuries” (pCi). If the radon level in your home is 4.0 pCi/L or greater, contact your local health department or visit the KY Radon Program (KY DPH, 2017). Additional resources are also available at: https://www.uky.edu/breathe/ (UK-CON, 2020).

The lower the radon level in your home, the lower your family’s risk of developing lung cancer (US EPA, 2016b).

If you, or someone you care about, wants to quit smoking, https://smokefree.gov/ can help (NCI, 2020).
ONE WEEK LATER...

HELLO!

WOW! THAT RADON LEVEL IS PRETTY HIGH. DON'T WORRY! AS A CERTIFIED RADON MITIGATION TECHNICIAN, I AM TRAINED TO FIX YOUR RADON PROBLEM. [22]

I SAW THE "NO SMOKING" SIGN IN YOUR YARD—THAT'S GOOD! BREATHING RADON IS HARMFUL FOR EVERYONE BUT MORE RISKY WHEN ALSO BREATHING TOBACCO SMOKE.

DR. RAY-DON IS NOT GOING TO BE HAPPY WHEN HE FINDS OUT ABOUT THIS.

WE'RE DOOMED!

I WISH THAT MITIGATION GUY WOULD STOP TALKING!

Radon Mitigation Timeline:
Visit #1
- Set up monitor
- Inspect house
- Fill holes & cracks

Visit #2
- Review radon values
- Discuss mitigation
- Sign contract

Visit #3
- Install mitigation system

I'D LIKE TO WALK YOU THROUGH THE MITIGATION PROCESS...


DON'T ENCOURAGE HIM!

GO AWAY!

HE'S NOT DOING ANYTHING.

WHAT'S HE DOING, NOW?!

WE ARE NOT HAVING A GOOD DAY.

HEY GUYS, CHECK THIS OUT!

[22] Always select a certified mitigation professional to help you reduce radon.
Visits 

Visit #2 (7 Days Later) 

Based on our measurements over the past week, the radon was 6.8 picocuries per liter. We recommend you install a "sub slab" mitigation system. [24] 

Visit #3 (9 Days Later) 

I'm almost done! This round part is the fan—it sucks radon gas from below your home to the outdoors—right above your roof. [25] 

All done! I'll return in 2 weeks to make sure the mitigation system is working as it should. Keep your eye on the pressure device in the basement to make sure your system is working properly. 

2 Weeks Later... 

Great news! The mitigation system is working great and the radon levels in your living room were less than 2 picocuries per liter today! 

You've made a great investment in your family's health. Be sure to check your radon levels every two years. [26] 

Thank you!
WHOOAAA! WHERE ARE WE GOING? 

I ran into Julie today at the grocery store. She wants to talk to us about testing her home for radon.

Less and less people are smoking tobacco, and we keep losing money.

Unacceptable! We must do better! We need to develop a campaign to attract new smokers!

Meanwhile... another place, another time.

Sir, the radium atoms in Section 3782 should start to decay any minute now. Bring them up on the screen, please.

To be continued.
**CAST OF CHARACTERS**

**Mom**
Loving, level-headed, and decisive: her family’s well-being is her top priority, and she leads by example

**Dr. Ray-Don**
Brilliant scientist, tactical wizard, commander of radon minions, and arch enemy of the lungs

**Radon Minions**
Odorless, tasteless, and colorless, radon minions cause widespread destruction by inflicting damage to DNA, cells, and/or tissue in individuals. Minions are loyal to Dr. Ray-Don and committed to causing lung cancer

**Dad**
Laid-back, protective and, sometimes, a bit stubborn. He is devoted to his family

**Susan Smart**
Public health researcher and advocate, passionate about reducing environmental risks for lung cancer, community leader

**Smokey**
Owner of the tobacco company “Slick Synergy”. An extravagant mastermind, he is desperate to revitalize the tobacco industry and increase cigarette sales

**Test**
Don’t be fooled by his easy-going nature: steadfast and committed, he poses a serious threat to the radon minions and is determined to help defend humans against radon

**Grey Bands**
Loyal to Smokey, these wisecracking jokesters love to socialize and hang out, but can also display a mean streak

**Radon Mitigation Expert**
Expert in reducing radon exposure in homes, friendly and approachable, loves problem-solving

**Tina**
Bright, confident, and curious; loves science and playing with Legos. She is empathetic and has a gentle personality

**Kit**
A Grey Band’s worst nightmare. Patient, spunky and incredibly strong, she hangs from high places, looking for Grey Bands
**CHEMICAL CHARACTERS**

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**Legend**

- ➔ "Decaying into"

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**WORKS CITED**
