An experiemental study to develop affordable non-invasive radon mitigation system for single-family dwellings

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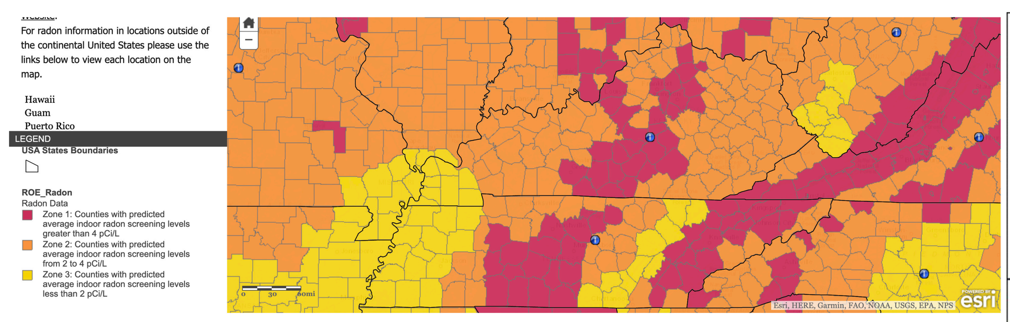
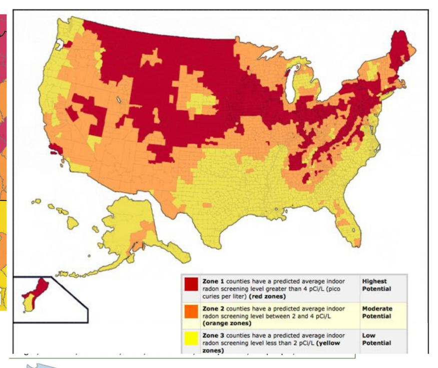
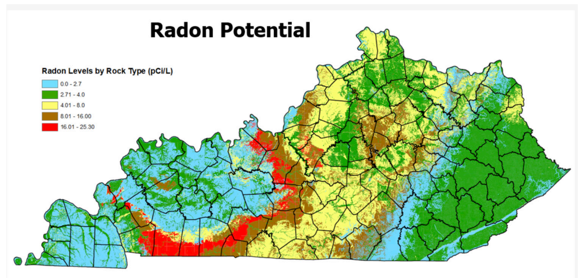
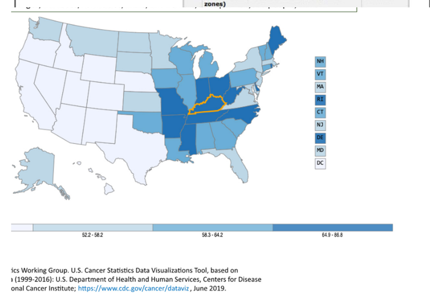
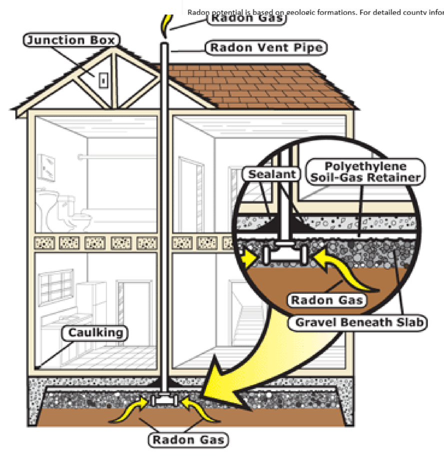
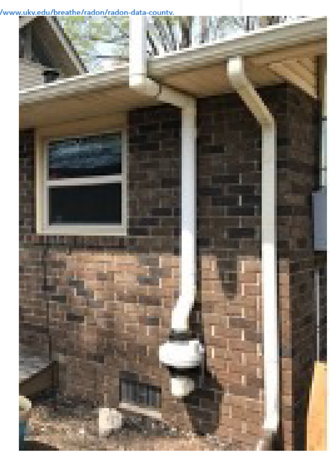
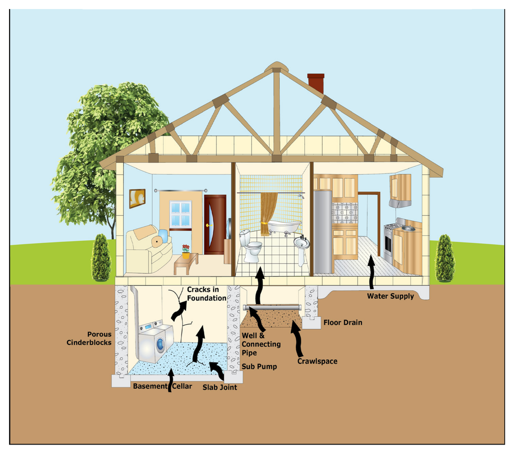
ABSTRACT

According to US Environmental Protection Agency EPA, each year, indoor radon gas causes around 21,000 lung cancer cases in the US. Radon exposure is the second leading cause of lung cancer after smoking. Further, exposure to radon is considered the number one cause of lung cancer among non-smokers. To reduce this health risk, indoor radon must be lowered using radon mitigation techniques. The current mitigation techniques are not affordable. This project aims at finding alternative mitigation system or measurable guidelines that can be embedded in the building operation and maintenance practices. The project team examined the effectiveness of using three building design parameters that haven't been systematically used for radon mitigation in the past; ventilation, air filtration, and detailing pattern. Environmental agencies consider these three parameters as factors that may affect radon concentration. However, they have never been used directly as a reliable mitigation system for high indoor radon levels. There are no guidelines that exist to inform the public on how windows, as means of natural ventilation, are used to lower the concentration of radon in a house. Furthermore, there are no guidelines in regard to what is the best type of filtration media that help in reducing radon's progeny in indoor air in an average house? To achieve this goal, in the current project we experimented different factors such as ventilation, air filtration, and affordable architectural detailing to mitigate radon in areas classified as Zone 1 by the US Environmental Protection Agency. In the current phase we tested 3 pairs of neighboring houses. We set one of each pair of houses as control, the other is a non-control in the experiment.

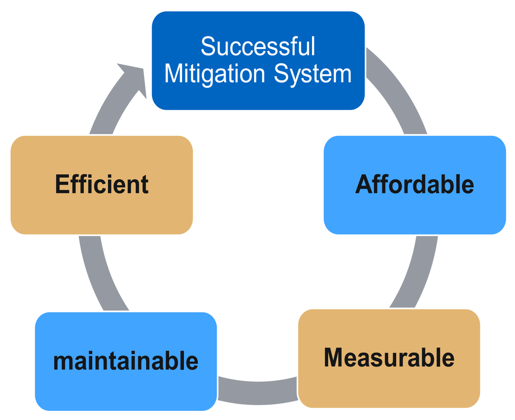
PROBLEM AND OBJECTIVES

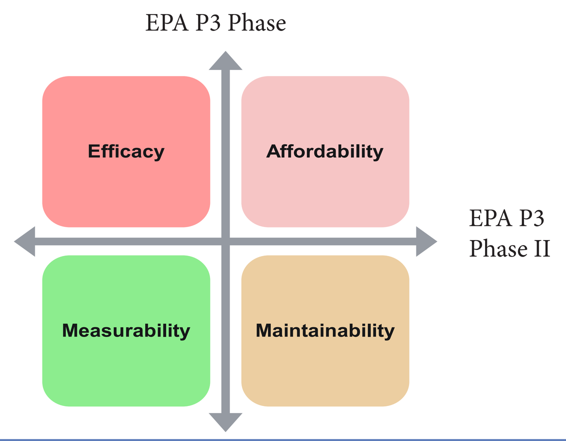




The indoor radon concentration is increased by either high source magnitudes under buildings or low ventilation rates. Current radon mitigation systems are built on the concept of making a depressurization system underneath the building being mitigated. This system collects the gas in a depressurized chamber and flush it out to the air using a fan and pipe connected to the depressurized chamber. This mitigation system is branched into two types based on how the fan operates; Active system, in which the fan is running mechanically using electricity to keep the system working, passive system, in which the same components of the depressurization system are used. However, the system operates passively; the fan is powered by the wind movement above the house. Active and passive depressurization mitigation systems are commonly used across North America and Europe. It costs an average of \$3000-\$4000 USD in the United States and requires an invasive installation process to cut a hole in the foundation, install a pipe and a fan inside or outside the building to get the radon gas from the soil to the outdoor air. The current project aims at finding alternative mitigation system or measurable guidelines that can be embedded in the building operation and maintenance practices.



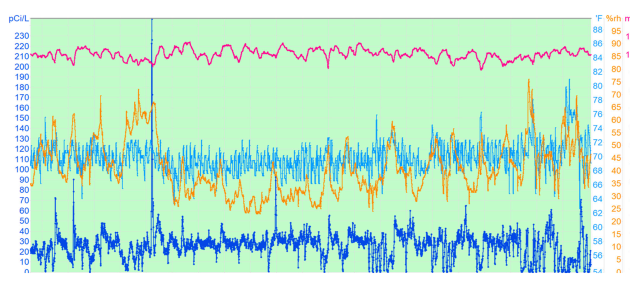


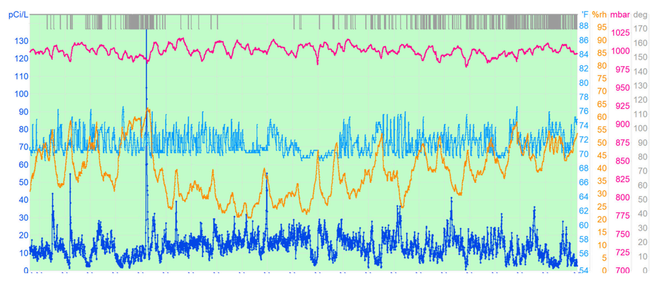
EXPERIMENT & RESULTS

GROUP 1
17% reduction


Control


Non-Control


Average indoor Radon - 4.8 pCi/L

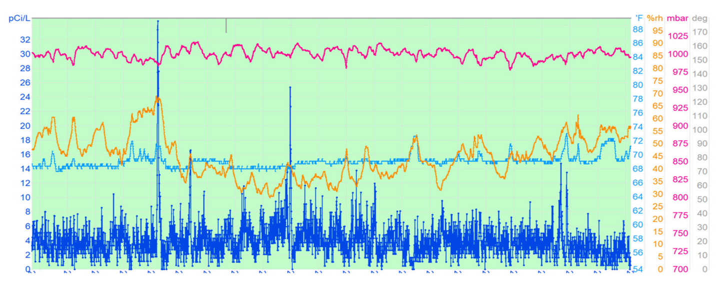

Average Indoor Radon - 4 pCi/L

GROUP 2
17% reduction


Control


Non-Control

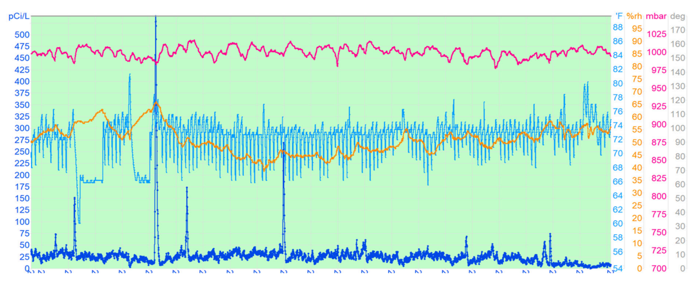

Average Indoor Radon - 26.4 pCi/L

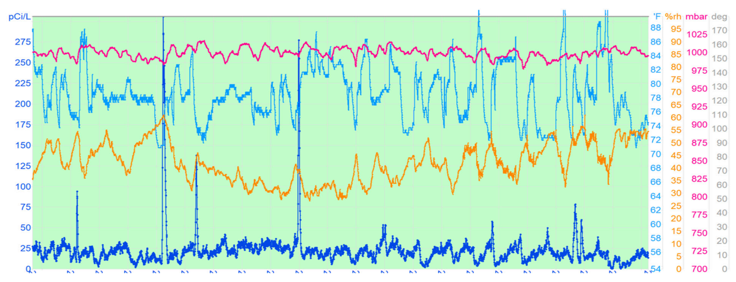

Average Indoor Radon - 22.0 pCi/l

GROUP 3
46% reduction


Control


Non-Control


Average Indoor Radon - 26.01 pCi/L


Average Indoor Radon - 14.00 pCi/L

We selected 6 houses with different characteristics and labeled them as three groups. The first group consist of two houses with basements that are located near the downtown of Bowling Green, Kentucky. The second group consists of two houses with slab on grade that are located in Warren County. The last group of houses are in Warren County. They are raised on a crawlspace foundation system. Each pair of houses have similar architectural design and heating/cooling systems. One of each pair of houses worked as a control for the experiment. The second house in each group was manipulated by different factors; natural ventilation, daily routine, utilize different types of air filtration. We utilized 6 digital monitors. The monitors were installed in the 6 houses to measure indoor radon around the clock for the period of the study, from October to April. The data included Radon pCi/L, Temperature °F, Humidity %rH, and Pressure kPa. The purpose was to monitor the level of radon in these houses throughout the cold months in Bowling Green, the season that has the highest levels of natural radon gas. The 2 different mitigation approaches (ventilation and air filtration) were manipulated in the 3 experimental houses. We used air filters with different Minimum Efficiency Reporting MERV Values. We also scheduled times for opening windows and ceiling fans operation. Each scenario was associated with a percentage of reduction/increase of radon concentration in each house. To propose the new guidelines and affordable radon mitigation system, we need to repeat the same experiment with intervening with some affordable building detailing and maintenance strategies. We plan to use simple exhaust fans. This intervention will be done in the winter months starting in the October this year.

MATERIALS



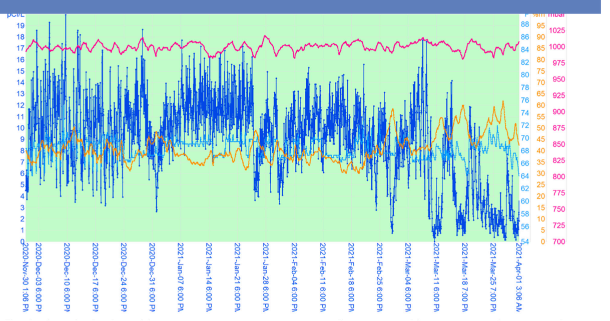


Figure 3. Indoor radon readings pCi/L aligned with indoor air temperature, relative humidity, and atmospheric pressure in house #3.

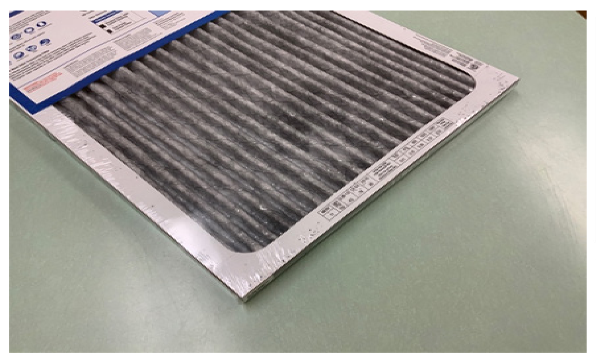
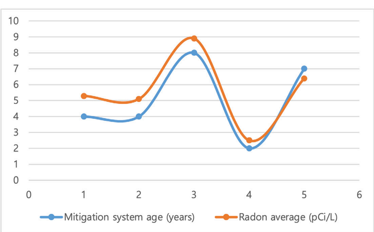



Figure 7. The correlation between the mitigation system age and radon averages.

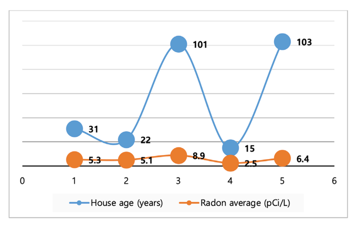


Figure 6. The correlation between house age and radon averages.

CONCLUSION AND DISCUSSION

According to the US Environmental Protection Agency (EPA), indoor radon is the second leading cause of lung cancer after smoking in the United States. EPA recommends a mitigation threshold for indoor radon, buildings that have indoor radon averages higher than 4 pCi/L should be mitigated. The mitigation systems available for single-family dwellings are based on making a depressurization chamber under the foundation to collect radon gas from the soil underneath the building, it collects the gas to flush it out to the outdoor air to be diluted to a safer level. These mitigation systems are not affordable to most of the population nor efficient to reduce indoor radon to safe levels in areas with higher outdoor radon. In the current project we experiment different factors such as ventilation, air filtration, and affordable architectural detailing to mitigate radon in areas classified as zone 1 by the US Environmental Protection Agency. In the current phase we tested 3 pairs of neighboring houses. We set one of each pair of houses as control, the other is non-control in the experiment. We tested them over the clock for six months during the fall and winter seasons, the seasons with higher indoor radon. We manipulated the interior environmental conditions by scheduling fixed time for natural ventilation. We also replaced the HVAC air filtration media with different and more efficient types on regular basis. The experimental houses showed significant decrease for indoor radon, however, the natural ventilation and affordable air filtration didn't bring the indoor radon to levels lower than 4 pCi/L. We extended our project for an additional year to be able to repeat the same intervention with manipulating some architectural detailing factors such as mechanical ventilation and building tightness in the coming winter months.

ACKNOWLEDGEMENT

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