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# Radon in Utah Homes

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Radon gas can be found nearly everywhere. It is formed by the decay of radium, which is found in rocks, soil, plants, and animals. Radon gas can become trapped in buildings and is dangerous at high levels. It is particularly known to be high in many areas of the state of Utah. It is important for the average citizen in Utah to understand more about radon and what levels they may be exposed to. An experiment was done to try an alternate, faster method of testing for radon gas. This experiment was performed in several different locations in Utah. While not as accurate as other typical methods, it was found that this method was useful for getting an idea of relative levels of radon between various locations. It was also a useful method for studying the decay curve of radon and radon progeny.

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## Introduction

Radiation is all around us. It is a common part of everyday life. There are traces of radiation in everyday objects from smoke detectors to building materials to the air we breathe. But it's no cause for immediate alarm. The level of radiation the average person is exposed to is usually low and relatively harmless. But it is important to be aware of when levels can become harmful.

Radiation can be split into two categories: ionizing and nonionizing. Nonionizing radiation has energy to heat food (microwaves) or send signals (radio waves, visible light), but unlike ionizing radiation, it does not have the energy to remove electrons from atoms and molecules [1]. Ionizing radiation is what most people think of when we say "radiation." It can remove electrons from atoms, causing damage to our cells [2]. Ionizing radiation includes x-rays, gamma rays, cosmic rays, alpha particles, or beta particles. Too much radiation exposure could lead to cancer, birth defects, or other problems [3].

Radon gas is one source of ionizing radiation. It is formed by the decay of radium, which can be found almost anywhere in rocks, soil, plants, and animals in varying levels [4]. We are all constantly exposed to radon gas, yet it's not normally a major issue. Radon gas is easily dispersed outdoors or in well-ventilated areas. On average our exposure to radon is relatively low, but it can seep through walls and cracks in foundations and get trapped [5]. It builds up in poorly ventilated areas such as basements or garages.

Radon itself is unstable, with a short half-life of only a few days [6]. As it decays further to become stable it emits alpha and beta particles. The heavy alpha particles (helium nuclei, two protons and two neutrons bound together) are easily blocked by our skin. However, radon and radon daughter particles can attach to dust particles in the air [7]. When breathed in these particles can cause damage to our lungs by emitting ionizing radiation within our bodies. Our bodies can heal from low levels of radon without serious damage, but being exposed to high levels of radon over long periods can increase the risk of lung cancer. Radon is the number two leading cause of lung cancer, after smoking [8]. Exposure to high levels of radon is especially relevant to many Utah residents, as the average radon levels in the state are high in many areas. As many as 41% of Utah homes have dangerous levels [9]. It is important for Utah residents to be aware of the risks of radon gas and the levels they may be exposed to in their homes.

## Theory

As radon gas decays, it emits three alpha particles and two beta particles before it can become stable lead (see Fig. 1). Adding up the half-lives of each of the decay products between Radon-222 and Lead-210 we get about 51.3 minutes. From this experiment we should expect to find that the half-life of each sample taken to be approximately that length of time. This could vary due to the random nature of particle decay, varying numbers and types of particles picked up in each test, or due to error in the methods used.

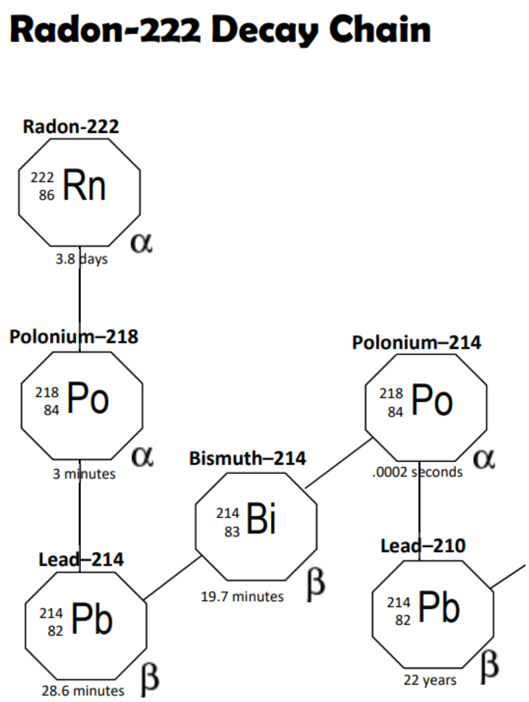


FIG. 1. Radon decay chain from Rn-222 to stable Pb-210. From [10].

Radon decays at an exponential rate until it becomes stable. This decay can be estimated using the equation:

$$f(x) = A_0 * e^{-\frac{x}{\tau}} + b \quad (1)$$

where f(x) is counts per minute, x is the time in minutes, $\boldsymbol{\tau}$ is the time constant or decay rate, and b is the background level of the room where the sample is taken. Detected radiation will decay exponentially until it settles at about the background level b.

There are several types of tests that are typically done to test for radon in a home. There are short term tests that can take from 2-90 days, or longer tests that take more than 90 days [11]. The approach used in this experiment, as described in the methods section of this report, is different from any of these tests. This experiment can be done in less than a day, which is much faster than the typical test, but also uses different units of measurement. The units used in this experiment will be counts per minute (CPM). A count happens when the detector on the Geiger counter detects radiation, such as an alpha or beta particle. Radioactivity due to radon is most often measured in picocuries per liter (pCi/L). There is no direct conversion from CPM to pCi/L, but a rough estimation can be done, as will be seen in the results section.

## Equipment

The equipment used for this experiment includes a handheld vacuum, filter, Kleenex, rubber band, Ludlum model 26 frisker Geiger counter, pc with the Time Lapse Creator software, and a webcam. Some of this equipment is shown in Fig. 2.


FIG. 2. Some of the equipment that was used for this experiment. On the left, a handheld vacuum with special filter and Kleenex attached with a rubber band. On the right is the Geiger counter used.

## Procedure

Several locations in Utah were chosen to perform this experiment. The locations were ideally poorly ventilated areas of basements. The locations chosen were the basement woodshop of the Science Engineering and Research (SER) building on USU campus, the basement of an apartment building in Logan, the basements of homes in Lehi and Draper, and the ground floor of a home in Springville.

The computer was set up first to have it ready for when the sample was collected. The webcam was set up at a good angle to view the Geiger counter. The time lapse software was set to take a picture every 30 seconds for the first 30 minutes. After 30 minutes, it was reset to take a picture every 2 minutes for 8-10 hours. The pictures were saved to a preset folder. A separate file was made for each location. It was found the time lapse software was very sensitive and could not be running at the same time as something else on the computer and the computer could not be turned off or time out, or the program would stop. The computer was set to never turn off when plugged in so the program would remain running for the duration of the data collection.

At each location an average of counts over one minute was measured for the background levels. A new tissue was put over the end of the filter, held with a rubber band, and the filter attached to the end of the vacuum. The filter had to be held on, as it wasn't a perfect fit for the vacuum used. The vacuum was run for 5 minutes to collect the dust sample, then the tissue was carefully removed from the filter and folded to keep the dust from escaping. The Geiger counter was placed over the folded tissue and using the time lapse computer setup, the counts per minute of the sample were recorded for about 10 hours for each test.

The data was input to an Excel spreadsheet, saved as a text file, and graphed through Gnuplot using equation 1, where b was the background level taken for the location.

## Results

The data was plotted through Gnuplot using equation 1. The graphs are shown below, see Fig. 3 - 7. Gnuplot returned the time constant $\boldsymbol{\tau}$ for each plot, along with the uncertainty. See Table 1 for these time constants and uncertainty.

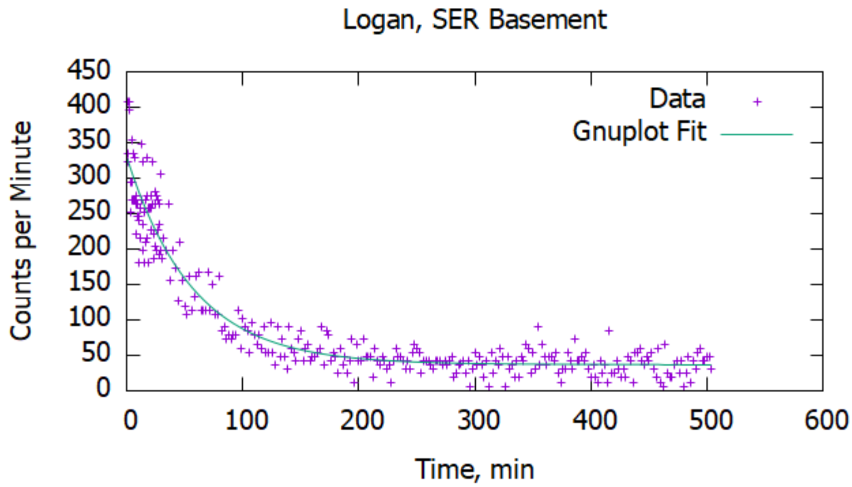


FIG. 3. Radon decay from levels found in the woodshop in the SER building on USU campus.

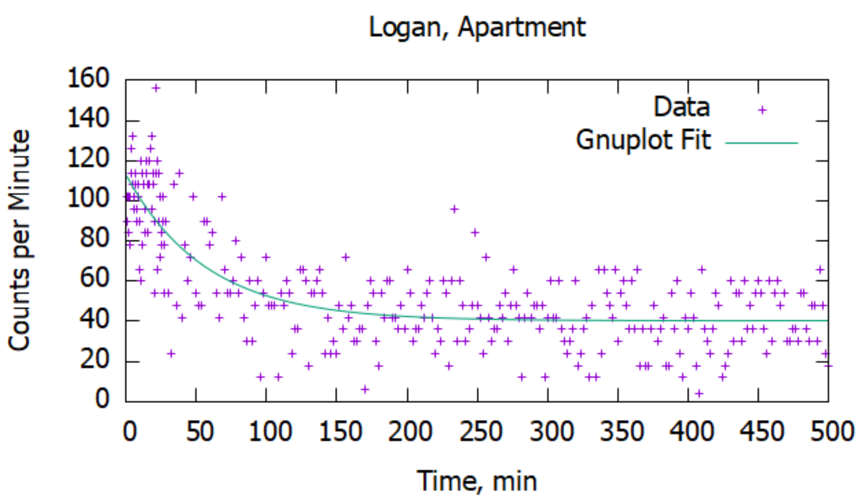


FIG. 4. Radon decay curve for an apartment basement in Logan.

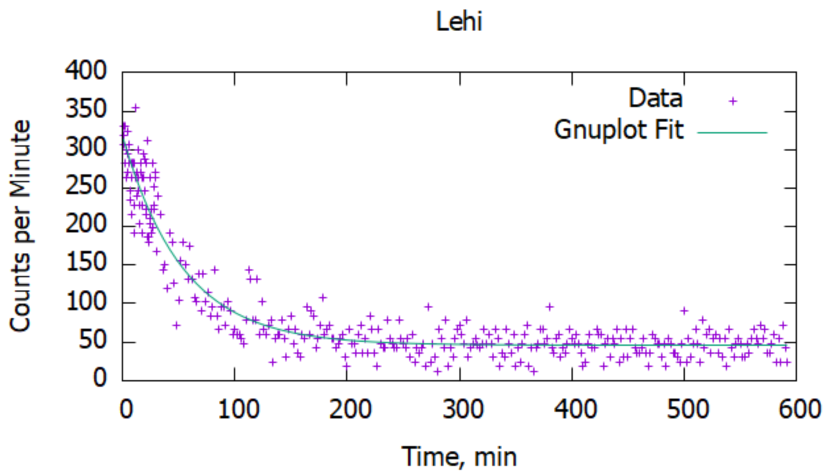


FIG. 5. Radon decay curve for the basement in a Lehi home.

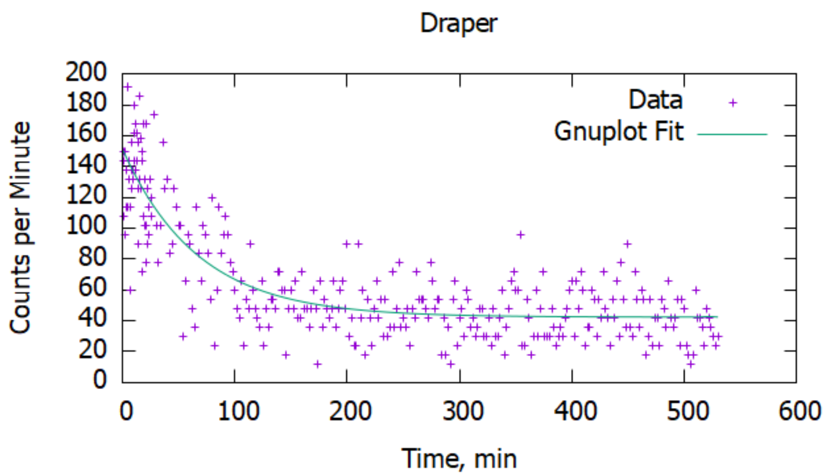


FIG. 6. Radon decay for the basement of a home in Draper.

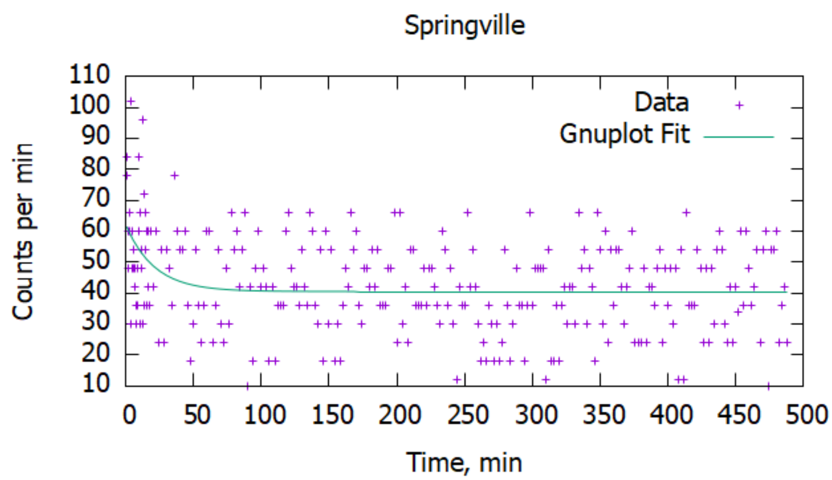


FIG. 7. Radon decay curve for levels found in a home in Springville.

TABLE 1. Time constants and error for each experiment location.

| **Location** | **Time Constant (minutes)** | **% Discrepancy** |
| --- | --- | --- |
| Logan SER Woodshop | $57 \pm 3$ | 5 |
| Logan Apartment | $57 \pm 7$ | 10 |
| Lehi | $54 \pm 3$ | 5 |
| Draper | $67 \pm 7$ | 10 |
| Springville | $20 \pm 10$ | 50 |

Most of the time constants found were reasonably close to the expected half-life of radon and radon progeny, which was around 51 minutes. The Springville time constant was very different from the others, less than half of what should be expected and with a 50% uncertainty. However, the radon level was apparently very low, and the signal was lost in the background noise.

It was found that the level of radon was relatively high in the SER woodshop on USU campus. The highest recorded count rate was about 400 CPM. In other locations it was much lower. For instance, in the Draper location it was found the high was around 200 CPM, and in Springville, only about 100 CPM. These levels fall in line reasonably well with other research done in Utah. Through other research it has been found that levels of radon right around USU campus are high, but other areas in Cache Valley are low to moderate (see FIG. 8). The results found in this experiment support these results as it was found that the SER building on campus was high and off campus in downtown Logan it was much lower.

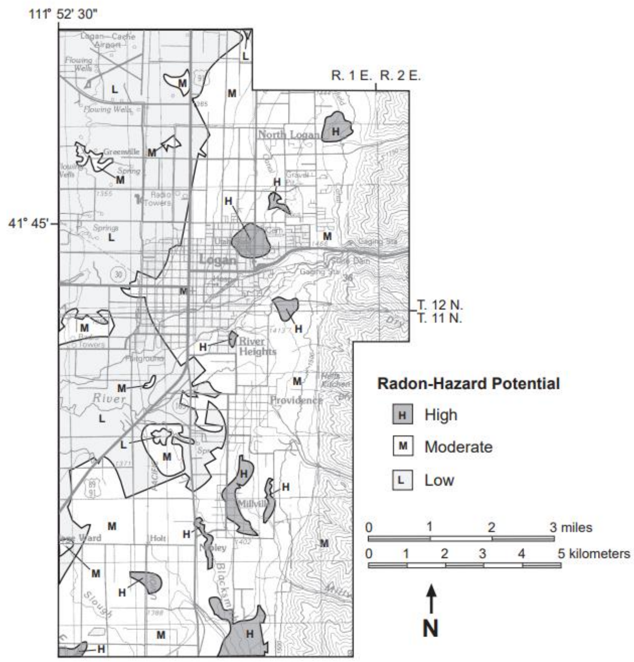


FIG. 8. Cache county radon levels. From [13].

It has been found through other research that levels in Lehi and Springville can both be moderate [12]. Yet in this experiment Lehi had the second highest level out of those areas tested, with a high reading of about 300 CPM and Springville had the lowest level at 100 CPM. However, these differences are not too surprising considering other factors such as age of the buildings, materials used in the building, ventilation, or soil content in the area. It has been found that buildings that are "(1) built on ground that contains sufficient uranium, (2) have underlying soil that allows easy movement of radon, (3) have porous building materials, cracks, or other openings below the ground surface that allow radon from soil to enter the building, and (4) have a lower air pressure inside than in the soil around the foundation" tend to have high radon levels [14]. Older buildings tend to have more cracks or other openings, and basements tend to have higher levels due to the fact they are deeper in the ground, and therefore closer to sources of radon. The home in Lehi is an older building, about 25 years old, and the test was done in the basement. The home in Springville is much newer, only about a year old, and does not have a basement due to a high water table in the area. Accounting for factors such as these, we can still say that the levels fall within a reasonable range that supports the other research done.

From these results we can see that this method is a useful way to quickly check relative levels of radon, although certainly not perfect. These experiments were done in less than a day each, whereas typical tests take several days or months.

Following an example calculation from “The Hot Balloon (not air)” paper, a rough estimation can be made for the level of radon in pCi/L [15]. An estimation was performed for the radon level in the SER Woodshop. The dimensions of the woodshop room are 5.02 × 5.4 × 3.8 + 5.02 × 3.1 × 2.9 meters $\approx 148.14\ m^3 \approx$ 148,140 L. One pCi/L is about 2.2 disintegrations per minute per liter of air. The highest recorded level in the woodshop was 400 CPM which we will approximate as 400 disintegrations per minute (DPM). This is not a true approximation as CPM is not directly converted to DPM. Disintegrations are how many atom disintegrations actually happen in a minute, while CPM is only what the detector reads [16]. Dividing 400 DPM by 148,140 L we see that the radon level found in the SER woodshop corresponds to approximately 0.003 pCi/L which is well within the level recommended by the FDA.

## Summary

In summary, this alternative method to testing for radon gave a good approximation for decay rate and was useful to see relative levels of radon in different locations faster than typical tests. Next steps going forward could include testing how levels of radon vary day to day and house to house, comparing levels of different rooms, or testing the effectiveness of different vacuums. It would also be helpful to test the effectiveness of different Geiger counters and find one that detects alpha particles well and can also provide a different unit of measurement. It is also planned to use the methods and data from this experiment to create a lab manual for future students to repeat this experiment in intermediate/advanced lab classes. Perhaps future students could improve upon the methods used and could pursue some of these possible next steps or find other directions to take this.

## Supplementary Materials

The supplementary materials for this report may be found in the file RadiationProject.zip, submitted to Canvas with this report. Included are data files and pictures, Gnuplot files and graphs, and notebook pages. See Table 2 for a summary of the archive file contents.

TABLE 2. Supplementary materials in “RadiationProject.zip”.

| Filename | Content |
| --- | --- |
| RadonNotebook.pdf | Scanned lab notebook pages |
| TextGnuplotFiles | Experiment data text files and Gnuplot files |
| Setup | Photos of lab setup |
| RadiationProjectGradphs | Graphs |
| RadonDataPics | Original data photos |
| Other | Other photos used in this report |

## Acknowledgments

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## References

[1] See https://www.epa.gov/radiation/radiation-basics; accessed 30 January 2023

[2] See https://www.cdc.gov/nceh/radiation/nonionizing_radiation.html; accessed 30 January 2023

[3] See https://www.omniaradiationbalancer.com/pages/ionizing-vs-non-ionizing-radiation; accessed 30 January 2023

[4] See https://www.epa.gov/radiation/radionuclide-basics-radium; accessed 30 January 2023

[5] See https://www.epa.gov/radiation/what-radon-gas-it-dangerous; accessed 3 May 2023.

[6] See https://www.imagesco.com/nuclear-science/geiger-counter/experiment-6.html; accessed 1 May 2023.

[7] See https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=406&toxid=71; accessed 1 May 2023.

[8] See https://www.epa.gov/radiation/radionuclide-basics-radon; accessed 30 January 2023

[9] See https://www.ksl.com/article/50556630/41-of-utah-homes-have-dangerous-radon-levels-association-warns; accessed 3 May 2023.

[10] See https://www.epa.gov/sites/default/files/2018-12/documents/radon-22-decay-chain.pdf for original image; accessed 28 April 2023.

[11] See https://www.cdc.gov/radon/radon-test.html; accessed 3 May 2023.

[12] See https://radonresources.com/directory/ut/ for "Lehi, UT Radon Mitigation and Testing" and "Springville, UT Radon Mitigation and Testing" (last accessed May 3, 2023).

[13] See https://ugspub.nr.utah.gov/publications/public_information/pi-46.pdf for original image; accessed 20 April 2023.

[14] See https://ugspub.nr.utah.gov/publications/public_information/pi-46.pdf for original image; accessed 20 April 2023.

[15] The Physics Teacher 33,344 (1995); https://doi.org/10.1119/1.2344235 Published Online: 04 June 1998

[16] See https://remm.hhs.gov/backgroundrad.htm; accessed 3 May 2023.