Investigating the Possibility of Using Carbon Nanostructures in Targeted Alpha Therapy:

A first batch of experiments attempting to use Activated Carbon to capture Radon shows negative yet inconclusive results

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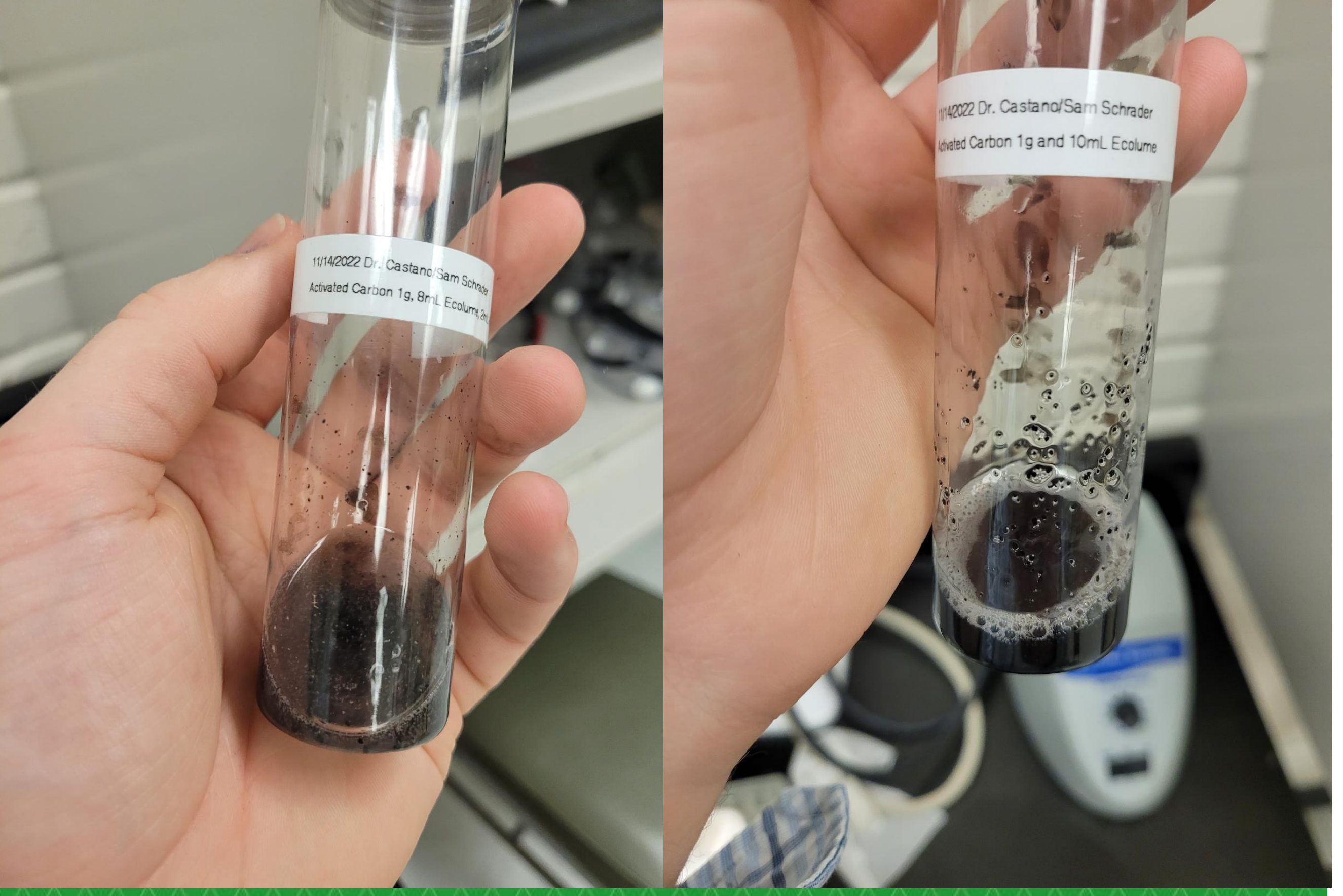


Figure 1: Samples of Activated Carbon in Liquid Scintillation Cocktails

BACKGROUND

Targeted Alpha Therapy (TAT) is a relatively new method of cancer treatment that employs nanoparticles containing alpha-active radioisotopes with short half-lives (1-4) days. During TAT, these nanoparticles are coated with a cancer targeting agent, such as folic acid, so that they attach to cancer cells when traveling through the body. After the nanoparticle has attached to the cancer cells, the alpha-decay of the radioisotope contained in the nanoparticle can destroy the cancer cells while causing minimal damage to the rest of the body. Despite yielding more promising results that traditional methods of treating cancer such as chemotherapy, TAT is still widely unavailable due to the extreme scarcity of the radioisotopes currently used for it, such as Lead-212, Astatine-211, or Cesium-134. These radioisotopes are either very rare or very difficult to produce. Astatine-211, for example, can only be used in roughly 100 treatments per year due to the difficulty of producing it.

OBJECTIVE

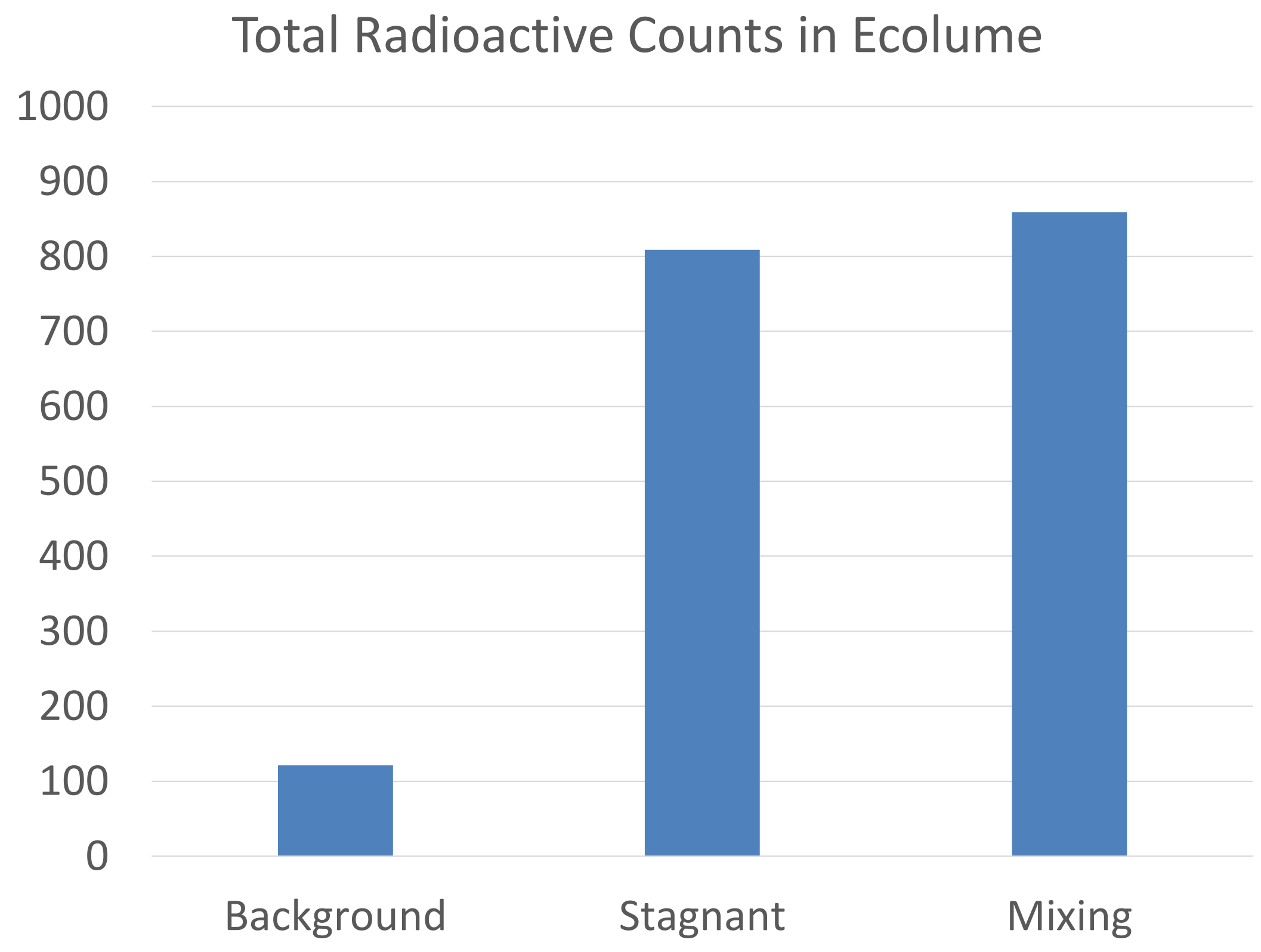
The goal of this research project is to explore the possibility of designing a nanoparticle for use in TAT that contains far more abundant radioisotope: Radon-222. Radon-222 is very common, being a part of Uranium's decay chain and therefore very easy to find in nature. However, it is also a chemically inert noble gas, making it impossible to form strong chemical bonds. However, some materials can have inert gases loosely attach to their surfaces in a process called adsorption. Adsorption is well documented in Carbon nanostructures, making them a good candidate for investigating. Should it be possible for Radon-222 to attach itself to a carbon nanostructure, it would open up pathways to further investigation into designing a nanoparticle for TAT that uses Radon and could make a scarce treatment far more available.

KEY EXPERIMENTS AND RESULTS

Limitations to the materials we had on hand led to all experiments being performed with activated carbon. To measure radioactive activity in our experiments, the tool we chose was a Liquid Scintillation Counter (LSC). LSCs detect radiation by counting photon emissions in liquid samples. While we struggled at first to make a sample that could be read due to activated carbon darkening the sample (see Figure 1). By using very small amounts of carbon, grinding it into powder, or a combination of the two, we could have the sample become relatively clear (see Figure 2). While we did various simple experiments to try and yield data, two experiments had the largest consequences for the project thus far.

KEY EXPERIMENT 1: ECOLUME RADON ABSORBTION

In this experiment, we exposed two samples of our liquid scintillation cocktail, Ecolume, to air containing a high concentration Radon-222. One sample was left stagnant, the other was mixed with the gas. Both samples were then compared to exposing the Ecolume to a background environment. The results showed that exposure to the Radon increased the radioactive activity in the Ecolume, meaning that in order to get meaningful results with the carbon, we could not expose it to the Radon at the same time as the Ecolume we would dissolve it in.



KEY EXPERIMENT 2: ACTIVATED CARBON EXPOSURE TO RADON

In this experiment, four samples of activated carbon were prepared. Two samples were ground into powder, and two were left in granular form. One of each sample was exposed to Radon-heavy air for 24 hours while the other samples were left in a background environment. Afterwards, measurements were taken, and found that the activated carbon had not adsorbed much Radon due to only a small increase in radioactivity. This indicated that exposure is not sufficient for adsorbing Radon onto activated carbon.

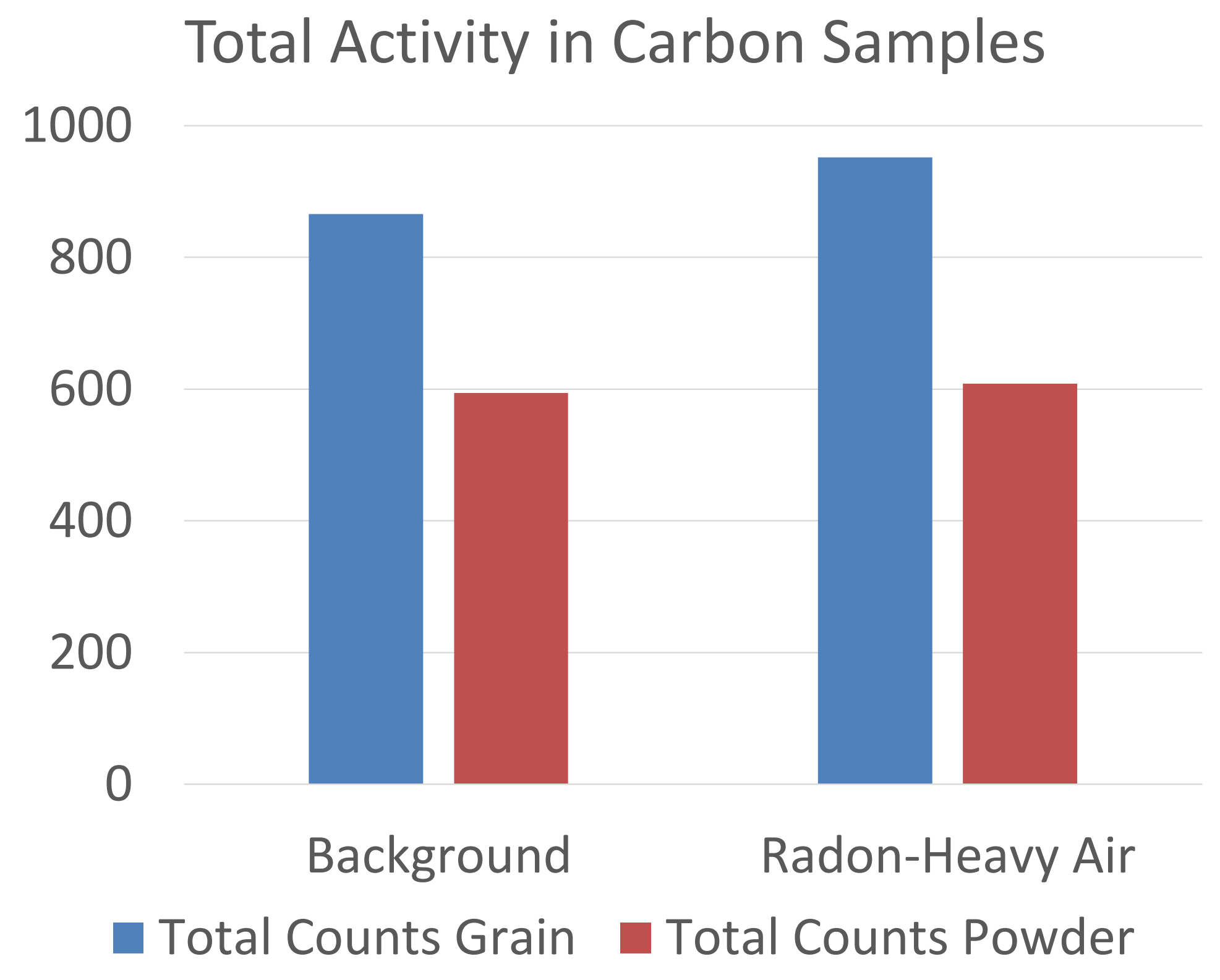


Figure 2: Samples of Powdered Activated Carbon in Liquid Scintillation Cocktails

SUMMARY

Although the results of the experiments didn't show significant adsorption of Radon-222 to activated carbon, it doesn't mean Radon-222 is out of the question for future use in TAT. There are two main routes for further research: exploring other methods of exposure and testing other carbon nanostructures.

Other methods that could be tested include:

- Making the activated carbon into a finer powder, the direction we're currently taking
- Inducing airflow in the glovebox where the Radon-heavy air is contained
- Designing a filter that would force the Radon to pass over the activated carbon more often

Untested Carbon Nanostructures include:

- Nanodiamonds
- Nanohorns
- Nanotubes
- Graphene

Further exploration with these new methods and materials may yield positive results in the future.

ACKNOWLEDGEMENTS

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Articles used:

Gibson, N. M., Luo, T.-J. M., Shenderova, O., Koscheev, A. P., & Brenner, D. W. (2012). Electrostatically mediated adsorption by nanodiamond and nanocarbon particles. *Journal of Nanoparticle Research*, *14*(3), 700. https://doi.org/10.1007/s11051-011-0700-9

Mendoza-Ortega, E. E., Dubois, M., & Krafft, M. P. (2020). Fluorocarbon Gas Exposure Induces Disaggregation of Nanodiamond Clusters and Enhanced Adsorption, Enabling Medical Microbubble Formation. *ACS Applied Nano Materials*, *3*(9), 8897–8905. https://doi.org/10.1021/acsanm.0c01651