Radiation and Radon from Natural Stone

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The natural and varied colors of natural stone countertops in home kitchens and other rooms have long been seen as stylish and impressive. In fact, their natural beauty makes them the center of attention in rooms that are otherwise painted and tiled in simple single colors. They are durable and resistent to stains and heat. As a result of their high heat capacity, which keeps them cool even in warm kitchens, experienced bread-makers often prepare dough directly on them [1]. Their aesthetic value and durability adds real monetary value to the homes that have them.

It is thus not surprising that recent market research [2] implies the residential demand for natural stone countertops will continue to increase. The demand increased by 5% per year in the period from 2001 to 2006. The continued consumer preference for larger kitchens and more bathrooms are expected to continue to promote growth from the residential remodelling sector, which accounted for 70% of the volume in 2006. The August 2007 edition of Consumer Reports magazine [3] includes an article on stone countertops entitled "Countertops, The Hottest Rocks," and notes that these have "evolved from utilitarian work surface to stylish focal point." One might wonder, however, if homeowners that opt (at considerable additional expense) for natural stone countertops are putting themselves and their families in danger by doing so. It is certainly not well-known that natural stone could potentially be dangerous. This key question is the focus of this article.

Natural stone finds its way into homes as part of the bricks, cement, sheetrock, floor and wall tiles, as well as our beautiful heavy countertops. This stone is mined from the earth's crust in quarries, and then made available to home builders, throughout the world. The earth's crust contains elements that were originally produced in the (supernova) explosions of stars in our galaxy over the billions of years that the earth has existed. Some of these elements are radioactive, and therefore any building materials extracted from the earth's crust can potentially be radioactive too. So, perhaps the title of the Consumer Reports article noted above has a second, more insidious, interpretation.

The potential dangers of radioactive elements in homes are two-fold: one is "radiation" and the other is "radon." Radioactive elements, by their very nature, seek stability by decaying into lighter elements via the emission of radiation. This radiation comes in the form of energetic light particles - namely, "gamma-rays", "beta rays", and "alpha particles." These can enter the body from the outside and cause damage to cells and DNA, potentially causing cancer. Also, naturally occurring Uranium nuclei decay into an element called Radium, which produces an unstable gas called Radon. Breathing air that contains radon thus deposits radioactive elements directly into the soft-tissues of the lungs and can cause lung cancer.

According to articles made available by the industry that are typically the top results in web searches on the subject, stone countertops pose no danger whatsoever. An oft-

cited reference of this kind is an e-mail from Prof. D. Langmuir in 1995 [4]. This opinion was however based on a model, not experimental data, and there is no delineation of the assumptions that were made. There is thus no way to know if the opinion is of general applicability. A more detailed analysis [5] from the Cold Spring Granite company also indicates a very low risk. However, the quoted results apply only to the granite from this one quarry. Contrast this with the fact that websites such as graniteland.com now list as available 1600 different varieties of granite from 64 different countries! More recent research published in peer-reviewed journals, in which all assumptions and experimental methods are carefully and plainly described, calls this general lack of concern into question.

Before we go into the details on this reseach, it is important to point out that there is a low level of radiation surrounding all of us at all times. We need to understand this "background" before we can put into context the possible dangers from stone countertops in our homes above and beyond this background level. Here I need to use two different units, "milli-rem per hour" (mrem/hr) and "picoCurie per liter" (pCi/L) to give a sense of scale. The mrem/hr number is the relevant quantity for the absorbed dose from external radiation, while the pCi/L number is the relevant quantity for the radon in the air we breathe.

On average, we receive about 360 mrem per year (0.04 mrem/hr) from natural and man-made sources. The natural sources include radon emanating from the soil around our homes and the cosmic rays entering our atmosphere from space. Man-made sources include dental and medical X-rays, and appliances such as television sets and smoke detectors. Flying on a commercial airplane results in approximately 1 mrem per 1000 miles travelled, so every round trip from New York to Los Angeles results in about 6 mrem of additional exposure. Sleeping next to another person for 8 hours per night results in approximately 2 mrem per year due to the natural levels of radioactive potassium in our bodies. People that work in Grand Central Station in New York City are exposed to 120 mrem/year from the high Uranium content in the granite walls. Brazil nuts have 1000 times the radioactivity of most foods due to their radium content. So, we live in a world filled with radiation.

Now, to put the "mrem/hr" and "pCi/L" numbers for an additional exposure above background into context into terms of cancer risk, one must depend on the results of very complicated long-term studies on the relationship between the dose received and the incidence of cancer. This is subtle business. However, there are general guidelines. The excess risk of cancer from an additional exposure to radiation above that from background sources is estimated to be 4 per 10000 per rem. Thus, the exposure to a 4 mrem/hour radioactive source for a total of 250 hours would amount to one rem. If 10,000 people were all exposed to this one rem of radiation, 4 of these people (0.04%) would develop cancer as a result of this exposure. For radon, the risk assessment is phrased differently. If 1000 non-smokers breathed air that contained 4 pCi/L of radon over the course of their entire lifetime, 7 of these people would be expected to develop lung cancer as a result of the radon exposure.

The cancer rates are roughly linear in the exposure - doubling the exposure doubles the cancer risk. The U.S. Department of Energy (DOE) [6] and the Environmental Protection Agency (EPA) [7] have thus set limits on the excess amount of radiation and radon exposure, respectively, in order to insure the excess cancer risks are very small. The limit for the acceptable whole-body exposure to radiation to visitors of DOE research facilities

is 100 mrem/year, and these facilities locally enforce much stricter limits. The EPA suggests remediation for radon concentrations exceeding 2 pCi/L, and strongly recommends remediation for concentrations exceeding 4 pCi/L.

These administrative limits are our best guide of what levels of exposure are dangerous and what levels aren't. However, there is no safe amount of radiation or radon. There is no threshold for the onset of cancers that result from exposure to radiation or radon. If it is reasonably achievable to make the exposure zero, then that is by far the best approach.

Given these scales for the cancer risk from exposure to radiation and radon, let's turn to the published research. I have found approximately 20 articles published in peer-reviewed journals that describe direct measurements of the direct radiation and radon emanation from natural stone and other building materials. These results paint a slightly less rosy picture of the potential risks.

I found 95 data points [8] of the rate of radon emanation from specific natural stones used in construction in the literature. These results indicate the potential for both signficant direct radiation and radon emanation from measured stones. Indeed, a tight correlation between the radiation and radon emanation is typical, which is not surprising.

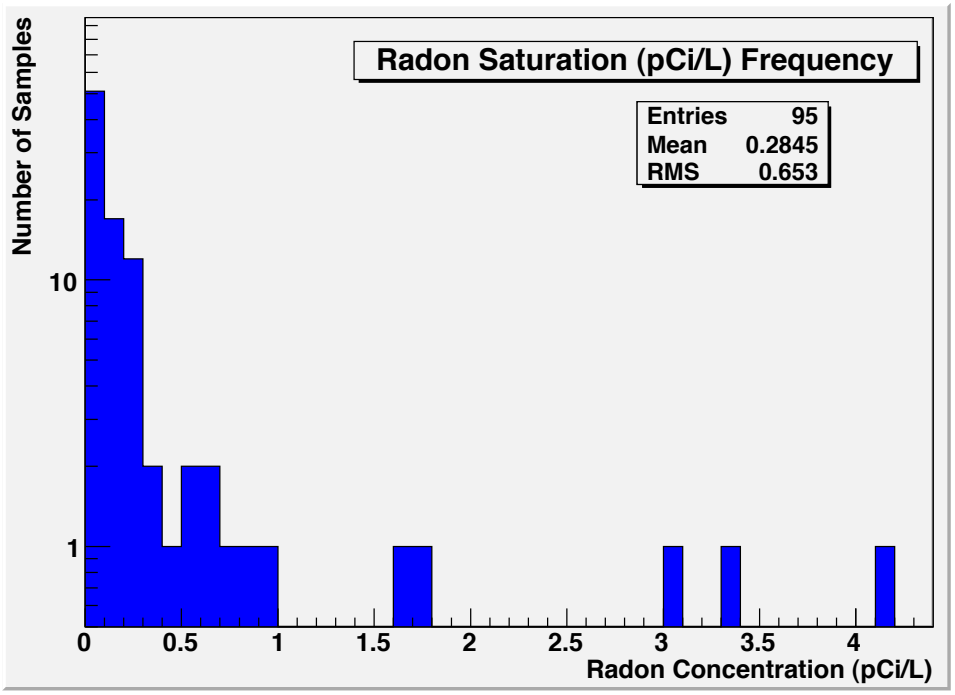

Figure 1: *The frequency distribution of the radon concentrationn (pCi/L) from various granites described in the published literature if placed in a hypothetical unventilated 20'×10'×10' room and assuming a granite surface area of 5 m^2.*

To give a feel for the radon concentration that would result from using these stones as countertops, I need to make a few assumptions. I will assume that there is 5 square meters (54 square feet) of surface area of this countertop and that it is sitting in an unventilated 20×10×10 foot room. Figure 1 indicates the saturation concentration of radon that would result in this hypothetical room. The vertical axis of this plot is the

number of samples, and the horizontal axis is the saturation radon concentration in pCi/L. One can see that the majority of the samples would result in a very low risk from radon (below 1 pCi/L). The mean value is ∼0.3 pCi/L. However, a handful of samples imply a saturation radon concentration of several pCi/L. The EPA would consider this dangerous assuming long-term exposure and would recommend remediation.

Similar results apply for the direct radiation. The majority of the stones are consistent with, or are only mildly above, the background, and hence do not pose a significant risk. A few however, emit radiation of several mrem/hr.

The home I visited as part of this story had natural stone countertops that, in general, emitted radiation at 0.1-0.3 mrem/hr, which is close to the background rate. In five specific locations on these countertops, however, the rate was 3-4 mrem/hour! This rate is a factor of some tens above background and is certainly not negligible.

I measured a section of this same countertop with a detector that was able to measure the energies of the emitted particles. As the decay of a radioactive nucleus produces particles of very specific and well-defined energies, the measurement of the energies of the emitted radiation directly and unambiguously identifies the nucleus that is decaying. The result is shown in Figure 2.

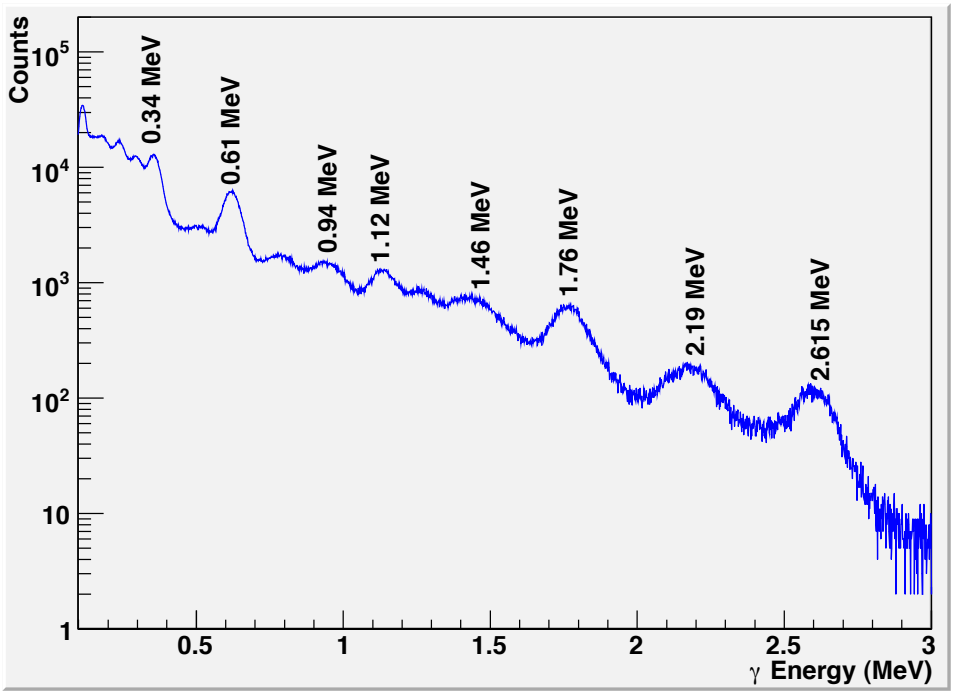

Figure 2: *The γ energy spectrum measured from a section of granite countertop from a home in the Houston area. The positions of the peaks directly identify the radioactive elements in this countertop. For the details, see the text.*

The majority of the peaks in this figure result from the decay of ^{214}Bi that is a progeny of ^{238}U. The countertop thus contains **Uranium ore**. Where there is Uranium, there is Radon. There is also an admixture of ^{232}Th (indicated by the 2.615 MeV peak from the decay of ^{208}Tl) and ^{40}K (indicated by the 1.46 MeV peak). The observed mixture of

Uranium, Thorium, and Potassium is consistent with all of the published literature.

These results imply that most natural stone countertops in the home are "safe," but some fraction are most certainly not safe. While the risk of cancer from these extreme examples is generally small and requires many years of exposure, "forewarned is forearmed," especially if there are pregnant women or young children in these homes.

If you own natural stone countertops, here are some suggestions. Ventilate your home as often as possible by opening windows - this exhanges potentially radon-laden air from the inside of your home with essentially radon-free air (at least in the Houston area) from the outside. The radon concentration in an unventilated volume of air reaches its saturation density in about 27 days - so open your windows for a half-day once every few weeks. Home radon test kits can be obtained at most hardware stores. Look for ones that state "meets EPA requirements," and follow the instructions on the test kit carefully. Radon decays with a half-life of about 4 days, so if the test kit needs to be shipped to a lab for analysis, do this expeditiously. Make sure that you follow the manufacturer's recommendations on the regular maintenance of your countertops, which typically call for regular resealing of the surface (once per year). Measuring the direct radiation requires at least a Geiger Counter, and these are not inexpensive. Feel free to contact me about this, or any other questions that you might have, via e-mail at the address listed below.

To summarize, natural stone naturally contains some amount of radioactive elements. The amount is most likely negligible compared to the other sources of radioactivity that we are unavoidably exposed to every day. In some cases, however, the amount can be significant. This fact raises some disturbing questions. Homeowners that have, at considerable additional expense, already installed natural stone countertops in their homes are now wondering if their beautiful stone is safe. This requires research on their part that they should not have been put in the position of having to do after the fact. It would make much more sense if natural stone countertops were checked for radiation and/or radon emanation by the EPA and/or the manufacturer, and thus officially qualified as "safe for homes" with respect to simple well-defined protocols before installation. Also, as the natural stone countertops installed in U.S. homes are quite commonly quarried abroad, there are also real Homeland Security concerns here. A number of companies sell detectors for use by port security personnel to detect radiation potentially indicating the makings of a "dirty bomb." These companies recognize [9] natural stone as a common false positive! Thus, shipments of large blocks of stone, or other common false positives, are presumably typically cleared through port security checkpoints without direct inspection [10]. Natural stone is dense enough that a significant amount of a much purer radioactive material could be hidden inside and not significantly increase the external radiation signature.

About the Author:

W.J. Llope is a Research Associate Professor of Physics at the T.W. Bonner Nuclear Laboratory at Rice University in Houston, Texas. His research concentrates on the physics of relativistic heavy-ion collisions at the RHIC accelerator facility at Brookhaven National Laboratory on Long Island, New York. He specializes in the detection of the particles emitted in these collisions via new high-performance and low-cost detector technologies. This expertise in particle detection applies as nicely to countertops as it does to heavy-ion collisions. Prof. Llope wishes to thank Daniel McDonald and Profs. Stan Dodds and Gordon Mutchler for helpful comments regarding the gamma spectrum measurement

noted in this article, and Judy Krieger for helpful comments on this text. Prof. Llope can be contacted regarding this article via e-mail at the address **SaxumSubluceo@gmail.com**. The comments received, his replies, and the late-breaking results from his ongoing studies of local stone countertops will be made available at the website **http://wjllope.rice.edu/SaxumSubluceo/default.html**.

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