

Response to a recent debate about radiation and radon in granite kitchen counter-tops

On May 8, 2008 radio station KHOU Channel 11 in Houston, Texas released a video that presented a one-sided account of radiation levels in granite and associated radon levels in homes that contain natural granite kitchentops. To support their account they engaged a particle physicist from Rice University to undertake radiation analyses of a number of kitchentops using a portable Na(I) gamma-ray spectrometer.

I have listened and watched the recent debate with some interest and absorbed the passionate, the informed and the uninformed responses that have been presented.

In all these responses there was one very conspicuous void – that of a qualified geoscientist who has the scientific and technical background and who has been intimately involved in the stone industry for many years.

The issue of radiation in granite and the emission of radon from the granite kitchen countertops has been raised a number of times over the last 15 years and there seems little doubt that the issue this time was also prompted by the quartz surfaces and plastic industry who are continually attempting to undermine the qualities/virtues of natural stone by misinformation crusades.

By publicly suggesting that kitchen countertops might be radioactive invariably elicits a degree of concern and panic among uninformed consumers. Consumers have neither the means to determine the radiation levels in their homes nor any avenue by which they can extract such information from the fabricators or wholesalers of stone. However, they can purchase relatively cheap radon meters and undertake a crude investigation of the radon gas levels in various parts of their homes.

Before addressing some of the individual issues let me emphasize that the accurate determinations of radioactivity in a stone, the radiation flux and the concentration of radon in the air are not straight-forward and are prone to large errors and subsequent misinterpretations. The values can also be manipulated and grossly overstated.

One of the most significant misinformed statements that can be made in this debate is to tar all granites with the same brush. There are about 2700 “granites” on the world market coming from dozens of countries. In the international stone trade the term “granite” is used very loosely. It is essentially a mercantile term embracing all those stones that have an igneous mode of formation, a high degree of crystallinity, and interlocking textures which resulted from an elevated thermal history that has approached or exceeded the melting point of the rock. The term includes “black granites”, true granites, the “general” granites, pearl granites, pegmatites, anorthosites, charnockites, gneisses, migmatites and a number of exotic varieties.

For example, the term “black granite” often causes some consternation among purists, academics and those not intimately associated with the stone industry. The two terms, in the strict sense, are contradictory. Granites in the broad sense are dominated mineralogically by subequal amounts of quartz, alkali feldspar, and plagioclase feldspar, which commonly collectively comprise around 90% of the rock and give them a light colour. Relatively small amounts of dark-coloured biotite and/or amphibole provide additional descriptors (e.g. biotite granite). Black granites usually contain little or no quartz, rare alkali feldspar, and typically much more-calcic plagioclase feldspar. Biotite and amphibole are usually present in only small to trace quantities; instead, calcic pyroxene and, less-commonly, Ca-poor pyroxene dominate the ferromagnesian mineral assemblage. Apart from these fundamental mineralogical differences there are many other gross differences between “true” granites and “black” granites, and indeed between any of the broad categories named above.

Basically every occurrence of granite (used from here in the broad sense of the word) is unique. The uniqueness stems back to its mode of formation including the history of the original source material, the chemistry of the magma, the oxidation state, temperature, and both the intrusive and post-intrusive histories of the magma. Once intruded and emplaced numerous geological and chemical processes can subsequently modify the original composition, mineralogy and texture of every granite. Much of the modification is a function of temperature and fluid activity, both of which have naturally occurring gradients. These variations lead to a range of different stones even over the scale of tens of meters. Geologically

young granites tend to be fairly simple mineralogically and texturally compared to many granites that are an order of magnitude older. It is worth noting that most unusual or “different” granitic rock types available on the world market (in terms of colour and texture) are at least Proterozoic or older (generally older than 1.5 billion years).

The idea of conducting tests on a single piece of granite countertop that might have been quarried several years ago from an area in the quarry or other location long abandoned is naïve at best. A value obtained from a test done on one slab does not necessarily become a characteristic of that granite. If a testing regime for radiation on a particular granite type is to ever be conceived it must be done with a rigorous geoscientific control of the granite pluton, its mineralogy and chemistry, and its setting. Without this fundamental geological information the value of any testing is next to meaningless. Even then, any testing that is done might still only be valid for that small section of the quarry.

Another elementary omission from the debate has been any discussion of the mineralogy of the different granites and how this has a bearing on the radiation issues. Reference was made to uranium ore being the cause of elevated readings of radioactivity. Although there was no intention to mislead the suggestion that there is uranium “ore” in a commercially available granite kitchentop is nonsense. If the granite body contained uranium ore it would not be a commercial dimension stone operation. Elevated concentrations of uranium in granite sufficient to be termed “ore” result in very unusual colours and textures (such as those at Roxby Downs, South Australia) in which the radiation has resulted in feldspar that has become almost black.

High localized readings of radioactivity in granite are the result of several possible geological processes. One is from the presence of sparsely scattered accessory minerals such as zircon, allanite, sphene and monazite that are intrinsic to granites. These minerals incorporate small to trace amounts of lanthanide and actinide elements into their lattices. Gradually, the uranium and thorium in these typically sparse minerals decay by various mechanisms and release tiny amounts of radon and thoron. Minerals that constitute uranium ore (mainly pitchblende, uraninite, torbernite) are exceedingly rare in commercial granites.

A second but similar source of radioactivity in granites is in the form of tiny inclusions within common ferromagnesian minerals such as biotite and amphibole. In the former, a range of accessory minerals such as apatite, zircon, thorite and thorianite accommodate most of the actinide minerals whereas the most common inclusion in amphibole appears to be apatite (a calcium phosphate mineral). The concentration of uranium and thorium in these accessory minerals is sometimes expressed by a pleochroic halo that is formed when the host mineral has suffered long-term damage from alpha-particle emissions.

In both these geological situations there is always the possibility for some localized concentration of the accessory minerals. In particular, the way some granites are formed involves the natural concentration of restite (residual) minerals. Where this occurs there could be localized elevated readings of radioactivity. Contamination from and/or partial assimilation of argillaceous country rock (such as mudstone and shale) by the intrusive granite as it forces its way to higher crustal levels can also lead to localized higher readings.

Uranium minerals can also form as a result of fluid activity within or associated with a granite body. It can happen during the formation of the granite, during emplacement of the granite or post-emplacement from external sources. High-level felsic granites may generate fluid activity that is able to scavenge uranium and thorium from the breakdown of some of the actinide-bearing accessory minerals and/or their hosts. Under certain conditions these fluids can permeate through the granite (mainly along grain boundaries) causing alteration of the feldspar to mostly kaolinitic clay and sericitic mica. The uranium and thorium can be adsorbed onto the clays and mica. As emphasized above, where such a geological process can be readily identified, the resulting granite type has become structurally weakened and is no longer a viable commodity for construction or use in the countertop industry.

High levels of fluid can also result in some localized geological “oddities” such as pegmatite. The huge grainsize and spectacular textures are in high demand because of their rarity. Their formation can involve the concentration of rare elements which either become incorporated into the structures of other minerals or, where sufficient, can form large and exotic minerals. If the fluids have scavenged some lanthanide and actinide elements there is a likelihood of creating sparsely occurring minerals containing elevated concentrations that lead to spikes in the level of radioactivity.

The possibility for the introduction of uranium into a granite from an external source must also be entertained. However, where this might have occurred there is clearly a sequence of events that has taken place and it only requires a modest amount of geoscientific research to establish this sequence. The fact that there is a localized high concentration of uranium sufficient to mine in proximity to a granite does not mean that the granite must also be high in uranium. For example, the granite might be 2 billion years old and the uranium deposit only 200 million years old with a geological fault that separates them. Each situation such as this must be evaluated geoscientifically on an individual basis.

At the other end of the “granite” spectrum, namely the black granites such as Indian Jet Black, Black Galaxy, and African Nero Assoluto), the amounts of potassium (^{40}K), thorium (^{232}Th), radium (^{222}Ra), and uranium (^{238}U) are typically much lower than quartz-bearing granite and both the level of radioactivity and consequently, level of radon emission, are very low. If you are concerned at all about radioactivity and radon in your home coming from your kitchen countertop think BLACK. This partly answers a question posed to the Rice University researcher regarding the presence of a broad relationship between the colour of granite and radiation levels. At the quartz-rich (felsic) end of the granite spectrum there is also a crude relationship between granite colour and levels of radioactivity. Because the majority of radiation emitted from felsic granites is from potassium (^{40}K) and not from the uranium (^{238}U) series as suggested by the physics researcher (commonly by a factor of 10) it follows that granites with an abundance of alkali feldspar are generally more radioactive and greater radon emitters than granites poor in this mineral. Most alkali feldspar in felsic granites is pinkish and accordingly many predominantly pink granites (often approaching “true” granites) emit higher levels of radiation than “normal” granites. Weathering and hydrothermal alteration of felsic granites also provide a fairly good correlation between radioactivity and colour because the resulting granite colour is often beige, yellowish or brownish due to the presence of clays and secondary micas (as noted above). Furthermore, because of their mode of origin the felsic granites also tend to concentrate some of the rare elements.

The issue of radon in general and radon in homes has been almost flogged to death. But just to summarize, radon is a daughter product of uranium. It has a half-life of just under 4 days, is inert, is tasteless and odourless, and has a density around 7.5 times that of air. Whereas radon is a daughter product of uranium there is an analogous daughter product (thoron) that is derived from the radioactive breakdown of thorium. Both gases are potentially harmful to humans in high concentrations and over long periods of time. Both are alpha particle emitters which when inhaled or ingested (as gas or dust) can expose sensitive body tissues at both cellular and molecular levels to the particles.

It must be emphasized that in most radon measurements the $^{220}\text{thoron}$ contribution is generally neglected because it is more difficult to measure accurately with common instrumentation, because there is a difficulty in obtaining representative mean values due to as yet poorly understood short and long-term concentration fluctuations, and because of its shorter half-life (about 55 seconds). However, what has been established is that thoron is ubiquitous in our environment and typically contributes to about 25% of the total signal. In some places it may be present in much higher concentrations than radon. Because its presence affects the radon measurement it also affects the dose evaluation.

The conventional wisdom to date concludes that the presence and concentrations of radon and thoron in houses is due to three principal factors, namely (a) lack of ventilation, (b) radon leaking from soil, and (c) radon emanating from building materials. However, there are a number of other very significant factors that directly affect the accurate and/or consistent measurement of radon and thoron. These include:

1. Being gas (and heavy) they are highly mobile because they flow and mix easily with air
2. The concentration and distribution in soil beneath and around a dwelling is often highly variable
3. The concentrations are related to variations in the composition of the underlying rock strata and rock fragments within the soil
4. Differences in the porosity and density of the soil (and even soil type)
5. Variations in the short- and long-term groundwater movement
6. Location and altitude of the dwelling, e.g. near substantial water sources
7. Height within a building and height above the ground level
8. Meteorological fluctuations, and even
9. Diurnal variations

Seismicity may also be a contributing factor to the radon gas flux in some areas.

Given these imposing collective factors how much reliance can be placed on the accuracy of domestic “radon” readings carried out by untrained people with \$5- \$10 radon meters whose activated films require mailing to a laboratory within a short time? The frenzy to purchase radon meters in Houston and other parts of the US as a result of the initial radio announcement is similar in a way to a clever and successful media stunt in Australia to ban the often deadly chemical dihydrogen monoxide. Dihydrogen monoxide can be highly dangerous in its natural form and is a common component of many dangerous toxins. It is responsible for thousands of deaths each year.

To put this radiation debate into some sort of perspective it is relevant to provide some general information on our radioactive environment (from the National Radiological Protection Board):

- 200 million gamma rays pass through the average human every hour
- 15 million potassium-40 and 7000 natural uranium atoms disintegrate inside the average human every hour
- 30,000 atoms disintegrate every hour in our lungs from the air we breathe giving off mainly α and β particles
- 100,000 cosmic ray neutrons and 400,000 secondary cosmic rays penetrate the average human every hour
- Every plane flight contributes a significant ‘hit’ of cosmic radiation to the body (check out the activity of a Geiger counter on a plane)

Also of relevance to this debate of naturally occurring radiation is the fact that radiological/epidemiological effects that can be directly attributable to continuous low level radiation are poorly understood because of the infinite other possible interactions in our complex environment and the intrinsic chemical and physical properties of the numerous relative daughter products of the ^{238}U , ^{235}U , and ^{232}Th decay chains.

It may be of interest to potential consumers of stone that certain varieties of engineered stone (quartz surfaces) consist of a framework of crushed granite particles. Boasting around 93% (by weight) of framework particles, petrographic analyses revealed the presence of the usual radioactive accessories, such as zircon, allanite, sphene and apatite, as well secondary clays and micas. If any studies are to be undertaken they should also include the altered and weathered brownish, granite-based synthetic products which would be expected to yield similar results to most common granites. Any testing authority must be aware that it is important to avoid being presented with only the relatively “clean” quartz pebble based engineered stone because of the inherently low level of radioactivity in quartz.

The synthetic surfaces industry has had a history of advertising misinformation verbally and in their written presentations regarding their own products and their natural stone competitors. An article written in 2005 entitled “Some aspects of engineered stone that is not usually advertised” could not get published in its long version by stone magazines because of the ostensibly potential litigious effects but, more honestly, the potential damage to the hip pocket in terms of advertising. The link below might be of interest. Some aspects might now be out of date because of new (Asian) producers and the inability to obtain samples from other suppliers – especially from the US. A condensed version of the article was released by the MIA as a newsletter. Although it faithfully portrayed the gist of the paper most of the details were omitted.

Another aspect that might be of interest is the movement in about 1985 in Australia to undertake studies of radiation levels and associated radon/thoron gas emissions from both domestic and imported stone. This follows the reported monitoring of stone for these products in Sweden and Canada. The movement fell through because of funding difficulties, because it was deemed unimportant in terms of health issues, and because there was a perception that it might adversely affect a small and fragile, domestic granite industry.

A final note is necessary on the rather ludicrous notion that regular maintenance of granite kitchen countertops (including sealing the surface annually) will in some way influence the radiation flux and radon emissions from that surface.

As for the ill-conceived and impractical idea on the testing of every slab, tile and block of stone that enters into the US and is produced in the US clearly the Rice University particle physicist has little knowledge of the diverse stone industry. All slate would require testing, all sandstone products (because of the possibility of thin beds of natural heavy mineral concentrations), all sand used for construction, the gypsum used to make plaster for walls and ceilings, and every aggregate source that uses its product to make concrete. In almost all dwellings these other construction products far exceed the amount of granite that is used.

A commonly encountered and quite serious problem these days is the function of the testing laboratory and laboratory personnel not only in the testing but also in the interpretation of the data. Laboratories (and that includes many university departments where instrumental testing is carried out) employ technicians who are trained in most aspects of instrumentation and in the conduction of certain tests. They are generally not trained in the understanding of the materials they are testing nor in the interpretation or significance of the results. Instrumentation specialists should limit themselves to the understanding of the instruments that they are using for testing and engage a suitably qualified scientist to assess and interpret the results, even when the testing appears to be straight-forward.

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