ASSESSING EXPOSURE TO RADON AND RADIATION FROM GRANITE COUNTERTOPS

EXECUTIVE SUMMARY

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Overview

Environmental Health & Engineering, Inc. has completed a detailed evaluation of potential human health risks of naturally occurring radioactive materials in granite countertops. The extensive measurements and rigorous mathematical modeling conducted to date indicate that (i) external doses of ionizing radiation emitted from granite countertops are well below levels that would pose a health concern and (ii) contributions from granite countertops to radon levels in homes are lower than background levels of radon exposure typically found outdoors and indoors.

Background and Objective

Both radon gas and low levels of ionizing radiation are natural constituents of the environment that we are exposed to every day, with most of our exposure arising from soil, cosmic and internal sources. The elements that produce radon gas and ionizing radiation are of course natural and are minor constituents of many common building materials such as concrete, brick, gypsum and natural stone. To address any potential health risk associated with the use of granite countertops in home settings, the Marble Institute of America (MIA) commissioned Environmental Health & Engineering, Inc. (EH&E) to design and carry out a series of experimental studies required to characterize radiation exposure and risk quantitatively.

The overarching question addressed by EH&E was whether granite countertops significantly increase exposures and doses of radiation in homes. A comprehensive study was designed to answer this question in a scientifically valid manner. The in-depth analysis focused on risks of exposure to radon gas and ionizing radiation associated with the majority of types of granite used as countertops in the United States.

Methods

To achieve these aims, numerous measurements were made in a systematic manner from multiple points on many varieties of stone sold as granite countertop. The testing protocol included (i) determining pertinent gamma activity concentrations, (ii) measuring total alpha, beta, and gamma emissions, (iii) measuring total external radiation dose; and (iv) determining radon flux from a wide range of representative stones. Results of the measurements were input into widely-accepted mathematical models to estimate annual doses of ionizing radiation and exposure to radon for a number of typical, realistic residential scenarios. To characterize potential radiation risks of granite countertops, the estimates of dose and exposure were compared to a variety of health-based benchmarks for radiation safety published by authoritative organizations charged with protection of public health such as the National Council on Radiation Protection and Measurements (NCRP).

Over 400 samples from 115 varieties of stone were evaluated that comprise approximately 80 percent of the annual U.S. market share for granite countertops, based on the most recent sales data available. Thirty-nine different slabs of countertop, representing 27 unique varieties of stone, were evaluated for emissions of radiation and radon on a full-slab basis. To increase the scope of the analysis, radon emissions were determined for one to nine discrete samples for each of another 88 types of stone plus 24 of the stone types for which full-slab testing was conducted. This collection of stones was selected to represent the types of stone that make up the majority of granite countertop sales in the United States as well as three "varieties of concern," based on descriptions in media reports. Three slabs for each "variety of concern" as well as for three randomly chosen varieties were analyzed in order to assess the amount of variability that can exist among slabs of the same type and to increase the likelihood of discovering any anomalies that may exist.

Results

Radiation Emissions

Direct measurements demonstrated that the annual dose for full slabs positioned parallel to and 6 inches from a human receptor is less than 0.3 millisievert per year (mSv a^{-1}) for

each of the stones tested. At this level, the European Commission recommends that building materials should be exempted from all restrictions regarding their radioactivity.[1] The United States has not established an exemption level for building materials based on radioactivity to our knowledge. All of the measurements were also well below the 1.0 mSv a^{-1} dose limit for the general public recommended by the NCRP.[2] The dose measurements are summarized in Figure 1 in order of decreasing market share.

The results presented in the figure represent conservative and therefore health-protective estimates of dose because they assume that the entire body of a person is 6 inches away from and parallel to the full slab for 4 hours per day. In practice, granite countertops are in a horizontal position, while a person is typically seated or standing when near to a counter. Accounting for the distance and horizontal position of a stone countertop relative to a person would result in lower actual doses. A modeling analysis confirmed by direct measurements showed that actual radiation doses would in fact be lower than the values shown in Figure 1.

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[1] European Commission. 1999. *Radiation Protection 112, Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials.*

[2] NCRP. 1993. *Limitation of Exposure to Ionizing Radiation*. NCRP Report No. 116. Bethesda, MD: National Council on Radiation Protection and Measurements.

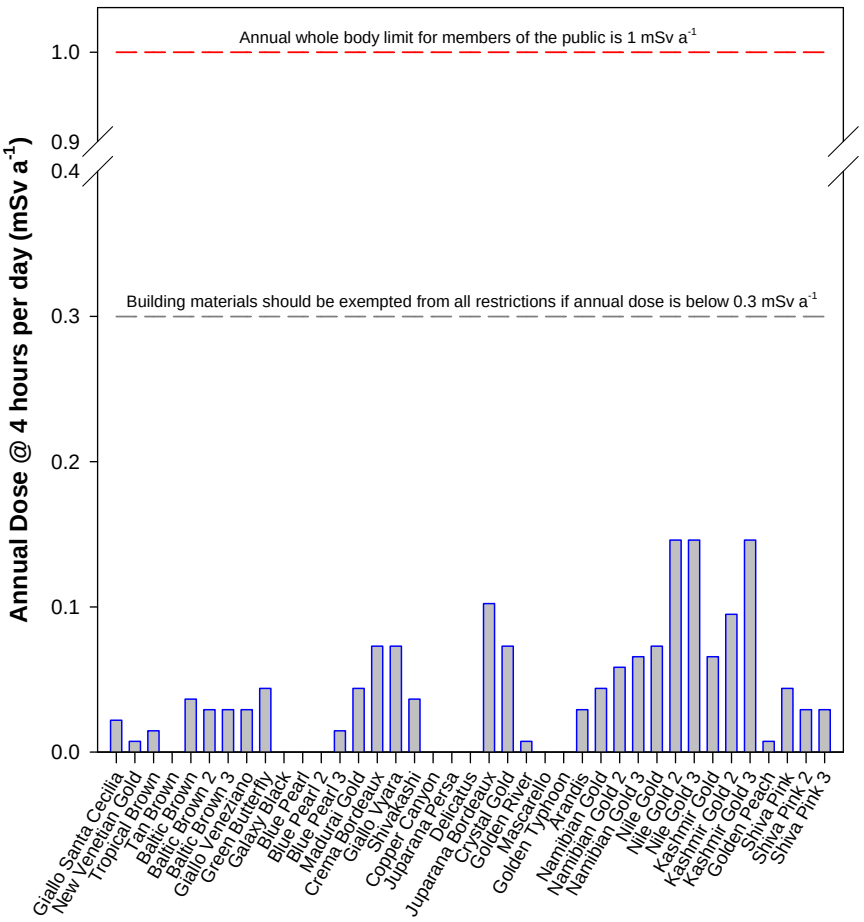

Figure 1 Annual dose (mSv a^{-1}) from gamma radiation for each variety of stone based on the median dose measured 6 inches from the surface of the slab and assuming that the full body of a person is parallel to the slab 4 hours per day for 365 days per year. Stone types are presented in order of decreasing market share.

Radon Emissions

The radon emission test results combined with the market share data indicate that the average predicted contribution to indoor radon from all stones tested is less than 0.01 picocuries per liter (pCi L^{-1}), a concentration that is well below both the average outdoor radon concentration in the United States of 0.4 pCi L^{-1} and the U.S. Environmental Protection Agency guideline for remedial activities to be undertaken of 4.0 pCi L^{-1}.[3]

[3] EPA. 1993. *Protocols for Radon and Radon Decay Product Measurements in Homes*. EPA 402-R-92-003. Washington, DC: U.S. Environmental Protection Agency.

Modeled concentrations of radon in indoor air that were estimated from the measurements of radon flux are shown in Figure 2. Emission rates, or flux, were measured in becquerel per square meter per hour (Bq m^{-2} h^{-1}) and then used to estimate contributions to radon in indoor air (pCi L^{-1}) accounting for ventilation and amount of granite countertop in the home. Similar to Figure 1, the results are presented in order of decreasing market share. The types of stone that constitute the majority of granite countertop sold in the United States are on the lower end of radon emissions and exhibit the least variability. This point is illustrated by the estimated radon concentrations for three slabs of the granite type known as Baltic Brown that can be found near the left end of the chart in Figure 2. Stone types on the higher end of radon emissions generally exhibited greater variability and account for less than 1% of the market share. The results for Nile Gold shown near the right end of Figure 2 are an example of a type of granite that exhibited greater variability among slabs.

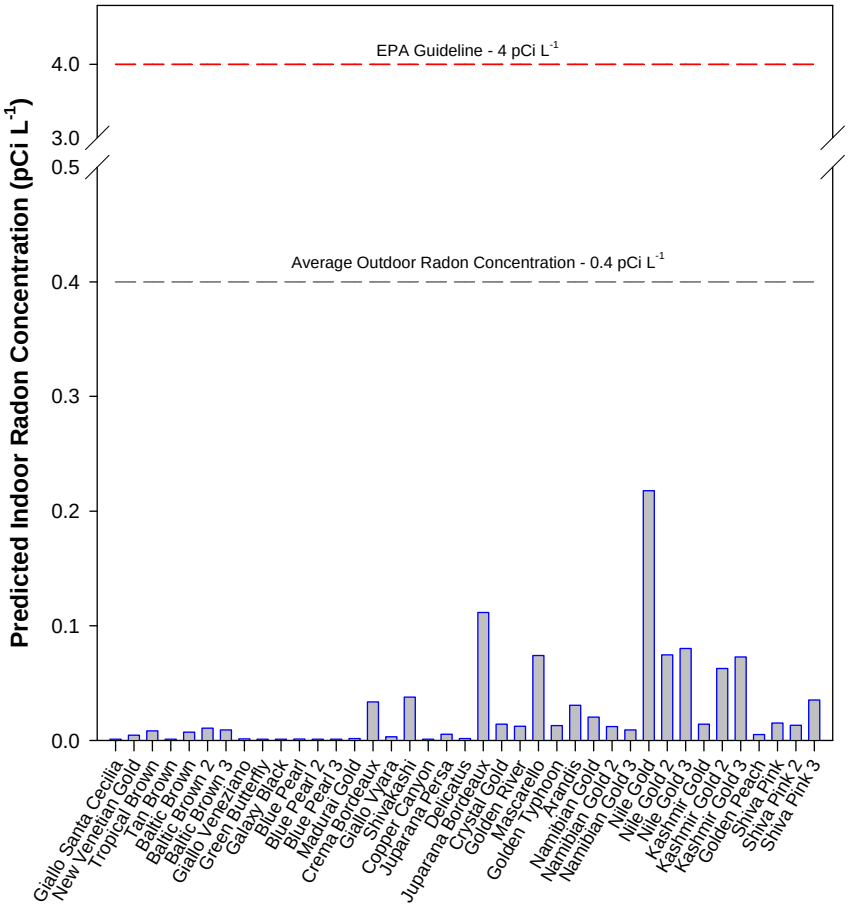

Figure 2 Full-Slab Testing—Estimated contribution to indoor radon concentrations by type of stone in order of decreasing market share.

The estimated contributions to indoor radon determined by testing of 213 discrete samples from 112 types of stone were all below background radon levels (Figure 3). All of the results for these stones fell within the range of radon flux and concentration values determined for whole slabs that are shown in Figure 2. Stone numbers and corresponding stone types are presented in the Appendix (Table A.1).

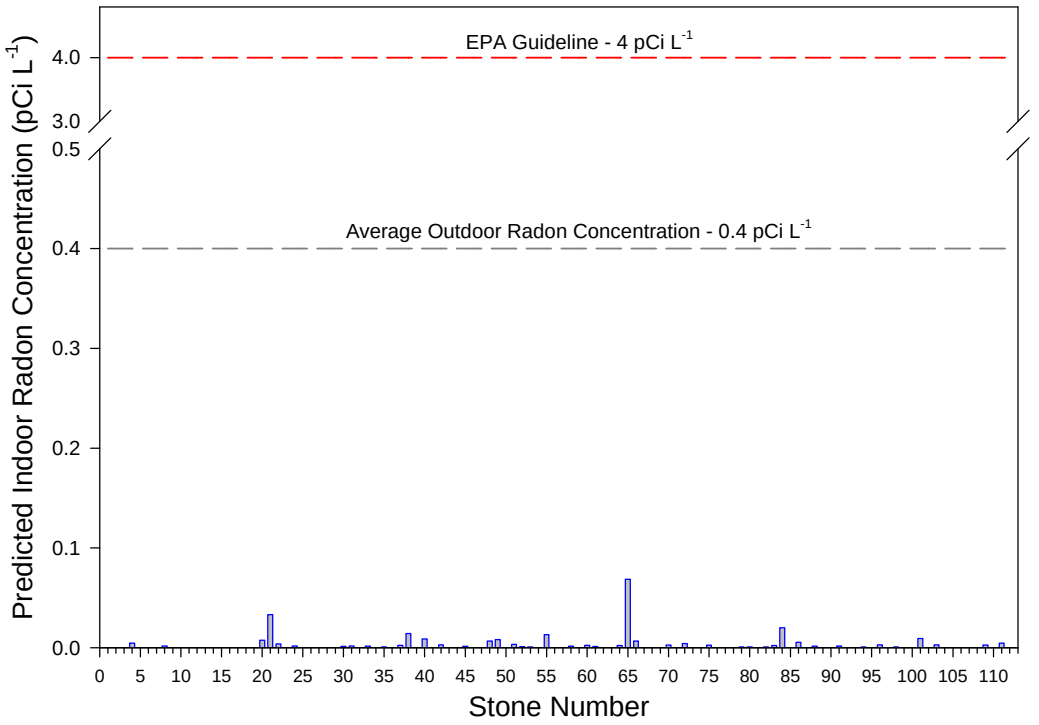

Figure 3 Discrete Sample Testing—Estimated contribution to radon concentrations in indoor air by type of stone in order of decreasing market share.

In summary, the analyses completed to date indicate that:

- Radon levels associated with emissions from granite countertops in homes are low in comparison to typical background levels of radon exposure. In other words, natural stone is a minor contributor to concentrations of radon gas within homes. These findings are consistent with an earlier review of the scientific literature that EH&E performed.[4]

[4] EH&E. 2008. *Natural Stone Countertops and Radon*. Environmental Health & Engineering, Inc. www.eheinc.com/stonecountertops.htm

- External dose associated with radiation emissions for all of the slabs tested are well below health-protective guidelines, including the exemption limit of 0.3 mSv per year recommended by the European Commission. The United States has yet to establish an exemption level for building products based on radioactivity to our knowledge.

- A portion of stones used as countertops may contain limited areas that are enriched in radioactive materials relative to the remainder of the slab. The areas of enrichment in the stones evaluated for this study make up a small proportion of the stone, on the order of less than 10 percent of the surface area. Detailed measurements of these enriched areas showed that they make a negligible contribution to potential doses of ionizing radiation.

- Assessing exposure to radon and radiation requires accounting for duration and frequency of exposure, not just absolute magnitude. Additionally, careful consideration of several key parameters is warranted. For radon, measurements of radon flux from a countertop must account for variability across the countertop surface, the effect of any backing material on the stone, and diffusion through the slab. It is critical that ventilation is accounted for when estimating radon concentrations in indoor air from measurements of radon emissions from stones. For radiation, distance and geometry must be incorporated into dose assessments.

- While significant variability was observed across stone types, the stones at the lower end of radon emissions were found to account for the vast majority of sales and also exhibited little variability among slabs. The varieties of granite countertop that exhibited the greatest variability of radon flux among slabs represent a small fraction of the U.S. market.

APPENDIX

Table A.1 List of Stone Numbers and Corresponding Stone Type from Figure 3

Stone No.	Stone Type	Stone No.	Stone Type	Stone No.	Stone Type
1	Verde Ubatuba	39	Golden Crystal	77	Zimbabwe Black
2	Santa Cecilia	40	Yellow River	78	Yellow Bamboo
3	New Venetian Gold	41	Bianco Romano	79	Ivory Coast
4	Tropical Brown	42	Typhoon Green	80	African Ivory
5	Giallo Ornamental	43	Key West Gold	81	Coffee Brown
6	Tan Brown	44	Dakota Mahogany	82	Magma Gold
7	Premium Black	45	Amber Fantasy	83	Wild Sea
8	Baltic Brown	46	Emerald Pearl	84	Sage Brush
9	Giallo Veneziano	47	Yellow Star	85	Colonial Gold
10	Giallo Portofina	48	Juparana Golden	86	Rosewood
11	Suede	49	Mascarello	87	African Fantasy
12	Verde Butterfly	50	Calacatta	88	Delerium
13	New Caledonia	51	Espirito Santo	89	Cambrian Black
14	Verde San Francisco	52	Sucuri	90	Peach Red
15	Galaxy Black	53	Coral	91	Gold Coast
16	Sapphire Blue	54	Blues in the Night	92	Santa Fe Brown
17	Giallo Fiorito	55	Typhoon Bordeaux	93	Paradiso Dark
18	Blue Pearl	56	Giallo Arctic	94	Red Montana
19	Tropic Green	57	Volga Blue	95	Solarius
20	Madura Gold	58	Autumn Harmony	96	Castor Blue
21	Crema Bordeaux	59	Azul Bahia	97	Steel Gray
22	Bianco Antico	60	Carioca Gold	98	Juparana Lorean
23	Impala Black	61	Pauline Grey	99	Sodalite Blue
24	Crema Caramel	62	Juparana Fantastico	100	Rosa Beta
25	Giallo Napolean	63	Nepson Gold	101	Desert Dream
26	Black Pearl	64	Gold Leaf	102	Virginia Mist
27	Giallo Vicenza	65	Niagara Gold	103	Shiva Cream
28	Pokarna Green	66	Juparana Tier	104	Almond Mauve
29	Luna Pearl	67	Peacock	105	Nordic Black
30	Vyara	68	Red Dragon	106	Jurassic Green
31	Azul Platino	69	Costa Smeralda	107	African Tapestry
32	Bainbrook Brown	70	Kashmir Gold	108	Orion
33	Shivakashi	71	Labrador Antique	109	Ivory Gold
34	Copper Canyon	72	Seafoam Green	110	Juparana Tier Bordeaux
35	Juparana Persa	73	Marinace Green	111	Gabarone
36	Verde Peacock	74	Juparana Colombo	112	Zambezi
37	Delicatus	75	Golden Beach		
38	Bordeaux	76	Magma		