EPA-600/R-96-022
March 1996

Technical Basis for a Candidate Building Materials Radium Standard

Final Report

by
Vern C. Rogers and Kirk K. Nielson
Rogers & Associates Engineering Corporation
P.O. Box 330, Salt Lake City, UT 84110-0330

EPA Interagency Agreement RWFL 933783
Florida DCA Contract 94RD-30-13-00-22-003

DCA Project Officer: Mohammad Madani
Florida Department of Community Affairs
2740 Centerview Drive
Tallahassee, FL 32399

University of Florida Project Officer: Paul D. Zwick
Department of Urban and Regional Planning
431 ARCH, University of Florida
Gainesville, FL 32611

U.S. EPA Project Officer: David C. Sanchez
National Risk Management Research Laboratory
Research Triangle Park, NC 27711

Prepared for:
State of Florida
Florida Department of Community Affairs
2740 Centerview Drive
Tallahassee, FL 32399

and

U. S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before comp

1. REPORT NO.	2.	
EPA-600/R-96-022		

4. TITLE AND SUBTITLE	5. REPORT DATE
Technical Basis for a Candidate Building Materials Radium Standard	March 1996
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Vern C. Rogers and Kirk K. Nielson	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Rogers and Associates Engineering Corporation P.C. Box 330 Salt Lake City, Utah 84110-0330	11. CONTRACT/GRANT NO. EPA IAG RWFL 933783 DCA 94RD-30-13-00-22-003
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
EPA, Office of Research and Development **Air Pollution Prevention and Control Division** **Research Triangle Park, NC 27711**	Final; 4-11/93 14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES APPCD project officer is David C. Sanchez, Mail Drop 54, 919/541-2979. DCA project officer is M. Madani, FL Dept. of Community Affairs, 2740 Centerview Dr., Tallahassee, FL 32399.

16. ABSTRACT The report summarizes the technical basis for a candidate building materials radium standard. It contains the standard and a summary of the technical basis for the standard. (NOTE: The Florida Radon Research Program (FRRP), sponsored by the Environmental Protection Agency and the Florida Department of Community Affairs, is developing the technical basis for a radon-control construction standard. Results of the research conducted under the FRRP are presented in several technical reports.)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Construction Materials	Stationary Sources	13C
Design Standards		14G
Radium		07B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to Public	Unclassified	12
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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ABSTRACT

The Florida Radon Research Program (FRRP), sponsored by the Environmental Protection Agency and the Florida Department of Community Affairs, is developing the technical basis for a radon-control construction standard. Results of the research conducted under the FRRP are presented in several technical reports. This report is a summary of the technical basis for a candidate building materials radium standard. The report contains the standard and a summary of the technical basis for the standard.

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Section 1
INTRODUCTION

1.1 PURPOSE OF THE CANDIDATE STANDARD

Residential building materials, principally concrete, can contain small amounts of radium, which generates radon gas that can migrate into residences. Furthermore, radon daughters trapped in concrete emit gamma radiation that can cause exposures to building occupants. This portion of the standard defines acceptable limits for the concentration of radium in building materials.

1.2 CANDIDATE BUILDING MATERIALS RADIUM STANDARD

The candidate building materials radium standard is:

> No material used in concrete for the construction of habitable structures shall have a total radium concentration that exceeds 10 pCi/g, as measured in accordance with procedures contained in "Standard Measurement Protocols, Florida Radon Research Program" (Williamson and Finkel 1991). The radium concentration in concrete used in the construction of habitable structures shall not have a total radium concentration that exceeds 5 pCi/g.

1.3 WHY THE STANDARD LIMITS RADIUM

Radiation exposures from building materials to people can occur either from indoor radon or from external gamma radiation. Both the concentration of indoor radon and the level of gamma radiation from the building materials depend primarily on the total radium concentration in the materials. Thus, limiting the radium concentration in the building material limits the amount of potential exposure to building occupants from both indoor radon and gamma radiation. For typical concrete thicknesses (tens of centimeters), the

gamma radiation exposures yield about the same radium concentration limits in building materials as do exposures to indoor radon from the materials.

Section 2

TECHNICAL ANALYSIS SUPPORTING THE CANDIDATE STANDARD

The technical analysis supporting the building materials standard consists of the following three steps:

1. Determine building material performance objectives for potential radon and gamma exposures.
2. Calculate radium limit for indoor radon exposures.
3. Calculate radium limit for external gamma radiation exposures.

2.1 PERFORMANCE OBJECTIVES

Performance objectives were selected according to their consistency with other Florida Radon Research Programs. Specifically, the performance objectives are a selected fraction of the U. S. Environmental Protection Agency's (EPA) indoor radon (as radon-222) concentration guideline of 4 pCi/L (EPA 1992a) and the EPA's external gamma radiation criterion of 20 μR/hr for cleanup of off-pile lands associated with uranium milling (EPA 1992b).

Indoor radon and gamma exposures to occupants of residences can come from many sources in addition to the building materials. Soils under building structures constitute the major source. Accordingly, a reasonably conservative value of 0.25 has been selected as the fraction of the radon guidance and gamma radiation criterion attributed to building materials. Thus, the building material performance objectives are:

1. Indoor radon-222 concentration limit - 1 pCi/L.
2. External gamma radiation limit - 5 μR/hr.

2.2 INDOOR RADON CALCULATIONS

The calculations of indoor radon concentration from a concrete slab use the procedure and equation from Rogers et al. (1994). Rearranging Equation (5-6) of that reference gives

$$Ra = \frac{F}{\rho E \sqrt{\lambda D}\ \tanh\left(\sqrt{\lambda/D}\ X_c\right)}, \qquad (1)$$

where

Ra	=	radium-226 concentration limit in the concrete (pCi/g)
F	=	radon flux (pCi/cm^2 s)
ρ	=	concrete density (g/cm^3)
E	=	radon emanation coefficient (unitless)
λ	=	radon decay constant (2.06x10^{-6}/s)
D	=	radon diffusion coefficient of concrete (cm^2/s)
X_c	=	thickness of concrete slab (cm).

A simple approximation for F is obtained from Nielson et al. (1994):

$$F = Ch\lambda_v/(3.6x10^6), \qquad (2)$$

where

C	=	indoor radon concentration (pCi/L)
h	=	average indoor height of building (cm)
λ_v	=	dwelling ventilation rate (air changes/hour)
3.6x10^6	=	units conversion (cm^3 s/L hr)

Combining Equations (1) and (2) gives

$$Ra = \frac{Ch\lambda_v}{(3.6x10^6\ \rho E \sqrt{\lambda D}\ \tanh\left(\sqrt{\lambda/D}\ X_c\right)} \qquad (3)$$

The following values were used in the calculations:

C	=	1 pCi/L (performance objective)
h	=	240 cm
λ_v	=	0.25 air changes/hour

ρ = 2.1 g/cm^3
E = 0.11
X_c = 10 cm
D = 2×10^{-3} cm^2/s

Substituting these values into Equation (3) gives a radium limit of 4 pCi/g in the concrete. This is rounded to 5 pCi/g in the Standard.

The radium concentration limit in concrete readily converts to radium concentration limits in concrete constituents. Table 1 presents typical weight percentages of concrete constituents (Snoddy 1992):

Table 1. Typical weight percentages of concrete constituents.

Constituent	Weight Percent
aggregate	49
sand	39
cement	8
fly ash	4
Total	100

Since Table 1 shows that aggregate comprises about 49% of concrete, the concrete aggregate radium limit can be estimated as 4 pCi/g/0.49, or 8 pCi/g in the aggregate. A similar limit for sand is 10 pCi/g.

2.3 EXTERNAL GAMMA RADIATION MEASUREMENTS

Exposures from gamma-emitting radionuclides in the concrete were estimated by a slab with the same characteristics as given in Section 2.2. A 6x6-m area was assigned to the slab, and the gamma-radiation exposures were calculated with the MICROSHIELD computer code (Grove 1993).

The MICROSHIELD calculations gave a value of 0.95 μR/hr per pCi/g of total radium in the concrete. Thus, a radium limit of about 5 pCi/g for the concrete gives a potential exposure of 5 μR/hr. The corresponding total radium limit in the aggregate is 10 pCi/g, and that for the sand is approximately 13 pCi/g.

Section 3
CONCLUSIONS FROM TECHNICAL ANALYSIS

Potential exposures from building materials to occupants of dwellings occur from external gamma radiation and from indoor radon. The extent of these potential exposures is mainly determined by the radium concentration in the materials. Both indoor radon exposure limits and external gamma exposure limits yield a 5 pCi/g radium concentration limit in concrete and a 10 pCi/g radium limit in the aggregate for the concrete.

Section 4
LITERATURE REFERENCES

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