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Project Summary

Soil Radon Potential Mapping of Twelve Counties in North-Central Florida

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This report describes the approach, methods, and detailed data used to prepare soil radon potential maps of twelve counties in North-Central Florida. The maps were developed under the Florida Radon Research Program to provide a scientific basis for implementing radon-protective building construction standards in areas of elevated risk and avoiding unnecessary regulations in areas of low radon risk.

Calculated soil radon potentials reflect geographic variations by modeling the potentials as the rate of radon entry into a reference house that is successively modeled on the soils in each radon map region. Individual soil profile properties are defined by horizon from county soil survey data. Radon source properties are defined from aeroradiometric data and from soil radium and radon emanation measurements. Calculated rates of radon entry into the reference house are grouped into tiers for display on radon potential maps. Comparison of the calculated radon entry rates with indoor radon data yields a geometric standard deviation of 2.1 and indicates that the reference house is consistent with the aggregate properties of the Florida houses in the comparison.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Soil radon potential maps are being developed for Alachua, Citrus, Clay, Duval, Flagler, Lake, Levy, Marion, Nassau, Putnam, St. Johns, and Volusia counties in Florida. They are designed to show from soil and geological features the areas that have different levels of radon potential. The maps are being developed under the Florida Radon Research Program to provide a scientific basis for implementing radon-protective building construction standards where they are needed and to avoid the cost of unnecessary implementation where they are not needed.

Soil radon potentials are defined for mapping purposes as the calculated annual-average rate of radon entry from soils into a reference house. They are calculated to represent geographic radon source distributions, minimizing the influences of house and occupant variations, temporal variations, and political and institutional boundaries (city, county, etc.). The mapping approach consists of

a. Definition of radon map polygons (geographic areas on a radon map) from existing soil and geologic maps.

b. Definition of the soil profiles associated with each radon map polygon and their associated radon generation and transport properties.

c. Calculation of numeric soil radon potentials for individual soil profiles and an area-weighted average to represent each radon map polygon.

d. Grouping map units with similar radon potentials and plotting the radon map polygons by color-coded radon potential tiers.

Radon map polygons were defined by the digital intersection of STATSGO soil map units with digitized surface-geology map units. The intersections to define the polygons were performed with a geographic information system under ArcInfo format at the University of Florida GeoPlan Center. The STATSGO soil maps defined 29 units in Alachua County, 13 in Citrus County, 14 in Clay and Duval counties, 13 in Flagler County, 16 in Lake County, 21 in Levy County, 20 in Marion County, 11 in Nassau County, 20 in Putnam County, 18 in St. Johns County, and 21 in Volusia County. The map units occurred in multiple polygon areas in each county, ranging from about 40 to 120 polygons per county. When intersected by geology polygons, the number of map polygons was approximately doubled.

Soil profiles in each polygon were defined from county soil survey data compiled at the University of Florida Soil and Water Science Department for each horizon in each of several profiles. The data included horizon depth and thickness, density, textural analyses and classifications, water drainage characteristics, high water table depths and durations, and related physical properties.

Radon Entry Modeling

Soil radon potentials were defined to eliminate house and occupant variables by using a hypothetical "reference house" with invariant properties, including indoor pressure, ventilation rate, slab and foundation design and attributes, and other reference conditions. The reference house was modeled as if it were located on each of the soil profiles that made up the land areas of each map polygon to reflect the average differences and variabilities in radon potential between and within the map polygons. The annual-average rates of radon entry into the reference house were modeled using complete, multiphase radon generation and transport equations. They characterize indoor radon entry by both diffusion (concentration-driven) and advection (with pressure-driven air flow).

The soil radon entry modeling for the reference house utilized detailed soil profile data defined by county soil survey analyses and surface geology data. The detailed soil profiles analyzed with the reference house for each location included individual radon source and transport properties of each soil horizon. The reference house was defined with the approximate characteristics of Florida slab-on-grade single-family dwellings. It consisted of an 8.6 x 16.5m rectangular structure with a perimeter shrinkage crack between the floating floor slab and the stem walls. The indoor pressure, house ventilation rate, floor slab properties, and other house characteristics were based on typical values measured in Florida houses. The radon entry modeling represented soil moisture profiles under the reference house by an annualized distribution that was defined from the reported high water table depths and durations.

Since the map calculations utilized a fixed set of house and foundation characteristics and considered only vertical variations in radon source and transport properties, the 2-dimensional RAdon Emanation and TRansport into Dwellings (RAETRAD) model was used to develop a more efficient, 1-dimensional algorithm that gave equivalent results for the reference house. The specialized radon potential cartography algorithm was named RnMAP and was shown to approximate the reference-house RAETRAD analyses within about 5%. Most of this difference resulted from the finite-difference mathematics in RAETRAD compared to analytical radon calculations in RnMAP. The 1-dimensional radon generation and transport calculations in RnMAP define the sub-slab radon concentration, from which radon entry rates are computed with empirical functions for radon diffusion through the intact floor slab and for diffusive and advective transport through floor cracks. The empirical functions, fitted to the sub-slab soil properties, also define the coupling of the soil region to the reference-house slab properties based on corresponding RAETRAD calculations.

Radon Source and Transport Parameters

Radon potentials of each map polygon were calculated from the radon source and transport properties of the soil profiles comprising the polygon region. Radon source properties were estimated from National Uranium Resource Evaluation (NURE) aeroradiometric data for shallow horizons (0 to 2 or 2.5m), and from geological classifications of the soils for deep horizons (to 5m depth). The NURE data were averaged [to obtain a geometric mean and geometric standard deviation (GSD)] for each polygon from data in all flight-line segments within the polygon, and were converted from equivalent uranium concentrations to corresponding radium concentrations for the model calculations. Polygons not intersected by NURE flight lines were represented by the geometric mean and GSD of all NURE data for their geological classification in the county. The NURE flight-line data were partitioned digitally into map polygon segments with the same geographic information system used to define the map polygons.

Radon emanation coefficients for each of the NURE-based radium concentrations were defined from a measured trend of increasing emanation with radium concentration. The trend had the form $E \approx 0.15Ra + 0.20$ for radium levels below 2.3 pCi g^{-1} and remained constant at 0.50-0.55 for higher radium levels. The trend was based on emanation measurements from over 200 samples from the twelve counties. Most of the samples were from University of Florida soil-survey archives and corresponded to the soils used to develop the STATSGO soil maps. The remainder were from U.S. Geological Survey borings. To attain adequate precision at low radium concentrations, the radon emanation measurements utilized a new effluent technique that is described and validated in the full report.

Deep-soil radium concentrations were defined from surface geology classifications and radium measurements in a larger group of over 600 soil samples. These included the samples used for emanation measurements plus additional samples from the same sources.

Radon transport properties were estimated from soil profile physical data compiled for each STATSGO soil map unit. The radon transport properties (radon diffusion coefficients and air permeabilities) were calculated from empirical correlations with soil horizon water contents, porosities, and particle sizes. Soil horizon water contents were calculated from their height above the water table using soil water drainage data. Steady-state water balance calculations indicated that for water tables in the 5m or shallower range, sub-slab soil water contents were well-approximated by the soil drainage-curve moisture at a matric potential that was equal to the distance above the water table. Water drainage data compiled for each soil horizon in each soil profile therefore were directly interpolated from the horizon-to-water-table distance to estimate soil moistures. Field measurements of near-surface soil water matric potentials at 46 locations in Central Florida confirmed the range of matric potentials being used.

Calculation of Soil Radon Potentials

Soil radon potentials were computed by mathematically modeling the reference house as if it were located on each soil profile of each of the radon map polygons. The RnMAP calculations used the specific radon source and radon transport properties of the horizons in each soil profile. The radon potentials were calculated as the rate of radon entry into the reference house in annual units (mCi y^{-1}) to emphasize the long-term average nature of the radon potential estimates.

Radon potentials were calculated for each of several soil profiles in each polygon, at each of two or three seasonal water table depths. They then were averaged seasonally to obtain annual-average radon potentials, which in turn were averaged over the different profiles to represent each polygon. Radon potentials also were calculated for both low- and high-radium geology, and the applicable geologic classification was used afterward to select the appropriate values to represent each polygon.

Separate radon potentials were calculated for the estimated median of the distribution in each polygon and also for radon potentials corresponding to the 75, 90, and 95% confidence limits. The confidence limits were based on the geometric means and GSDs of radium computed from the NURE data distributions in each polygon and also on the varied properties of the different soil profiles that comprised the polygon.

Production and Interpretation of the Radon Maps

The resulting radon potentials were partitioned into seven tiers of similar numerical values for display on the radon potential maps. The tiers corresponded to the <0.4, 0.4-1, 1-2, 2-3, 3-6, 6-12, and >12 mCi y^{-1} levels of radon potential. This set of tiers provided suitable ranges for using a uniform tier scale on all of the radon potential maps. Map polygons were colored according to the appropriate tier classification for intuitive visual interpretation. However the numerical values of the radon potentials for each map polygon are presented in the report for more quantitative map interpretations. A radon potential of 3 mCi y^{-1} corresponds to approximately 3.9 pCi L^{-1} in the reference house.

Separate maps were plotted for the median, 75, 90, and 95% confidence limits of radon potentials to give a better perspective of radon potentials in a given polygon (region). Regions with low potentials on both the median and higher-confidence-limit maps exhibit reasonable assurance of having minimal indoor radon risk. Regions with high radon potentials on the median and higher-confidence-limit maps conversely have a relatively high probability of elevated indoor radon levels. Regions with low median radon potentials but high potentials for higher confidence limits are heterogeneous (low median; high GSD) and may have generally low radon potentials but occasional to frequent anomalies with high radon potential. Special considerations may be needed to define radon-protective building needs in these areas.

The calculated soil radon potentials were compared with 804 indoor radon measurements in the twelve counties from the state-wide land-based radon survey. The comparison was consistent with the reference-house indoor radon accumulation rate of 1.3 pCi L^{-1} per mCi y^{-1} of soil radon potential and with an ambient outdoor radon concentration of approximately 0.3 pCi L^{-1}. The GSD between measured indoor radon levels and those predicted from the maps was 2.08, which is the approximate level of precision associated with the calculated soil radon potentials. The total variation among measured indoor radon levels was partitioned to estimate a house variability of GSD=3.7, compared to soil variability on the order of GSD=2.2 to 2.4. Uncertainties are much higher in predicting an indoor radon level for a particular house than for predicting the median level in the reference house for a given polygon.

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***David C. Sanchez** is the EPA Project Officer (see below).*
The complete report, entitled "Soil Radon Potential Mapping of Twelve Counties in North-Central Florida," (Order No. PB95-159869; Cost: $38.50, subject to change) will be available only from

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