Proceedings of the American Association of Radon Scientists and Technologists 2008 International Symposium Las Vegas NV, September 14-17, 2008. AARST © 2008

SEASONAL RADON VARIATIONS IN UTAH TESTING RESULTS: SHORT TERM TEST RESULTS WITHIN 10% OF THE EPA THRESHOLD (4.0 PCI/L) SHOULD BE REPEATED IN A DIFFERENT SEASON

David Joseph Neville, Radon Program Coordinator[1]
John Douglas Hultquist, Radon Program Manager
Division of Radiation Control, 168 North 1950 West, Salt Lake City, UT 84114-4850.
Email at davidneville@utah.gov & jhultquist@utah.gov
Phone 1 (801) 536-4250.

ABSTRACT

Investigators in the Utah Indoor Radon Program conducted a study to observe the potential variations in seasonal radon measurement tests. Data from Utah's Newborn Test Kit database was utilized. Initial contact letters and email reminders were sent to participating home owners, who were mailed activated charcoal detectors on 28 January 2008. The data suggests that homes where radon test results fall within 10% the U.S. Environmental Protection Agency (EPA) action level of 148 Bq m^{-3} (4.0 pCi/L) should be retested during a different season, before mitigation actions are recommended.

Key words: radon; 222Rn; indoor levels; seasonal variations; radiation protection.

INTRODUCTION

Lung cancer is one of the deadliest forms of cancer. Recent articles reported that 13% of all lung cancers do not have a direct connection to smoking (Cowley and Kalb, 2005). Lung cancer is cited as the cause of death in 160,000 Americans a year—more than breast cancer, colon cancer, and prostate cancer combined. The Environmental Protection Agency (EPA) estimates that indoor radon is responsible for

[1] Note: Funding was provided by the EPA's State Indoor Radon Grant (SIRG) and the Utah Division of Radiation Control.

approximately 21,000 of these deaths (EPA, 2005). In 2007 surveys were conducted in Utah of radon mitigators certified by the National Environmental Health Association's National Radon Proficiency Program (NEHA-NRPP) regarding radon mitigation system installations. The survey found that 80% of home owners who choose to install radon mitigation systems did so as the direct result of an indoor radon test, conducted as the result of a real estate transaction, which indicated levels above the Environmental Protection Agency's (EPA) action level of 148 Bq m^{-3} (4.0 pCi/L). The Utah Department of Environmental Quality supports an Indoor Radon Program which encourages potential home buyers or sellers to "…include Radon testing as part of the home inspection process" (DEQ, 2007).

Seasonal variations of indoor radon levels have been noted in climates ranging from Alabama to Canada with humidity and precipitation being the primary cause (see McNees and Roberts, 2007; Chen, 2003; Steck, 1992; Zhang, et al 2007). We seek to further explore seasonal indoor radon testing variations obtained in homes built in dry climates that have snow capped mountains throughout the winter months. We affirm the statement of the Conference of Radiation Control Program Directors (CRCPD) and the Alabama Radon Program that "…suggests that other State radon programs should retest their known summertime negative radon tests during subsequent wintertime heating seasons to determine the extent of this problem in their State" (CRCPD, 2007).

The EPA recommends long-term (greater than 90 days) and short-term (less than 90 days) tests to determine indoor radon levels (EPA, 2005). Ford and Eheman (1997) remark "…a minority of people are retesting in accordance with current EPA recommendations." Most residential real estate transactions provide a short amount of time to allow a buyer to conduct home inspections and tests. This includes testing for indoor radon levels. Continuous Radon Monitors (CRM) may be utilized because of this shortened time frame. Data provided by the National Association of REALTORS® for Utah

(Figure 1), show that home sales increase as temperature levels increase and decrease as temperature levels decrease (NAR, 2008).

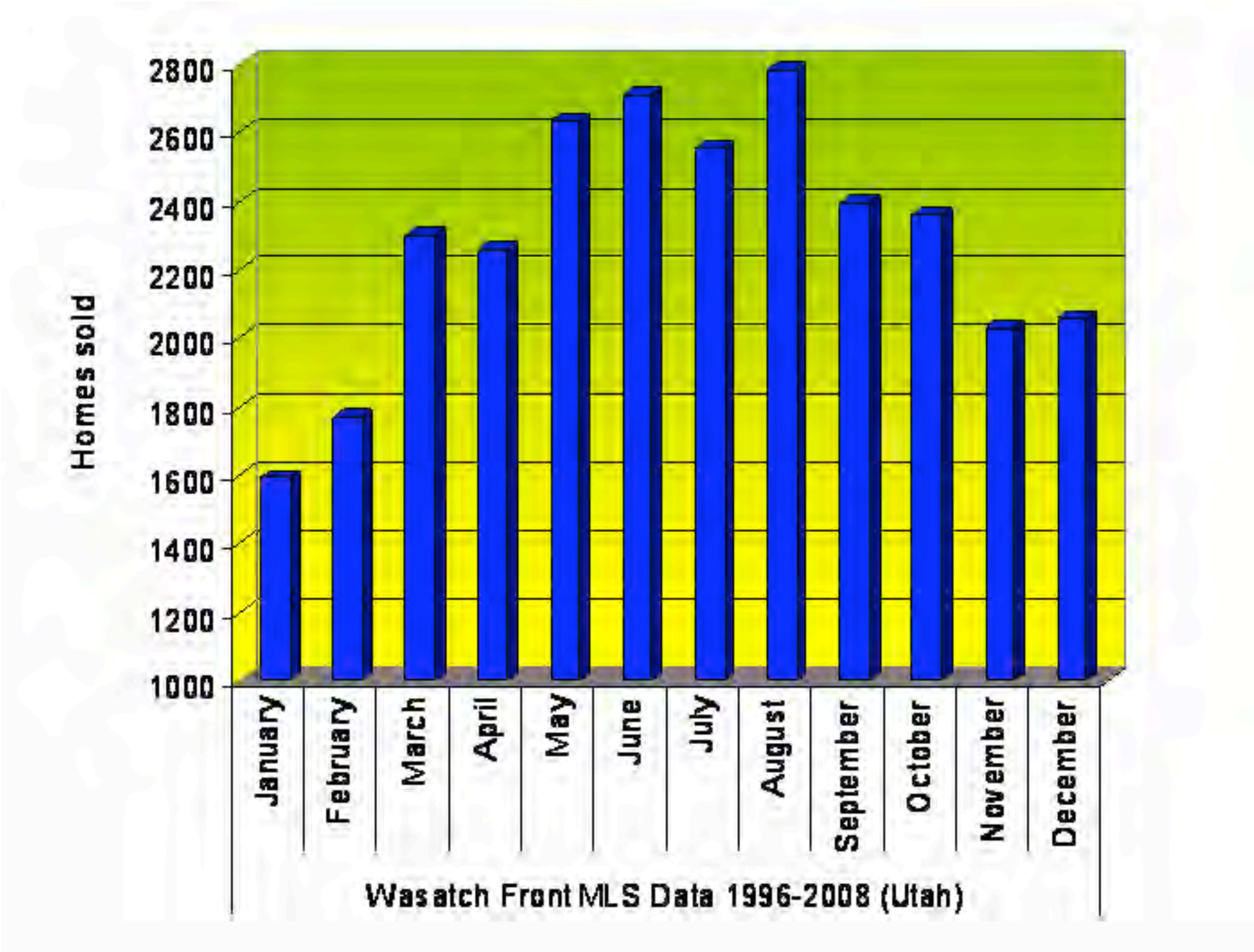


Figure 1. Homes sold by month in Utah

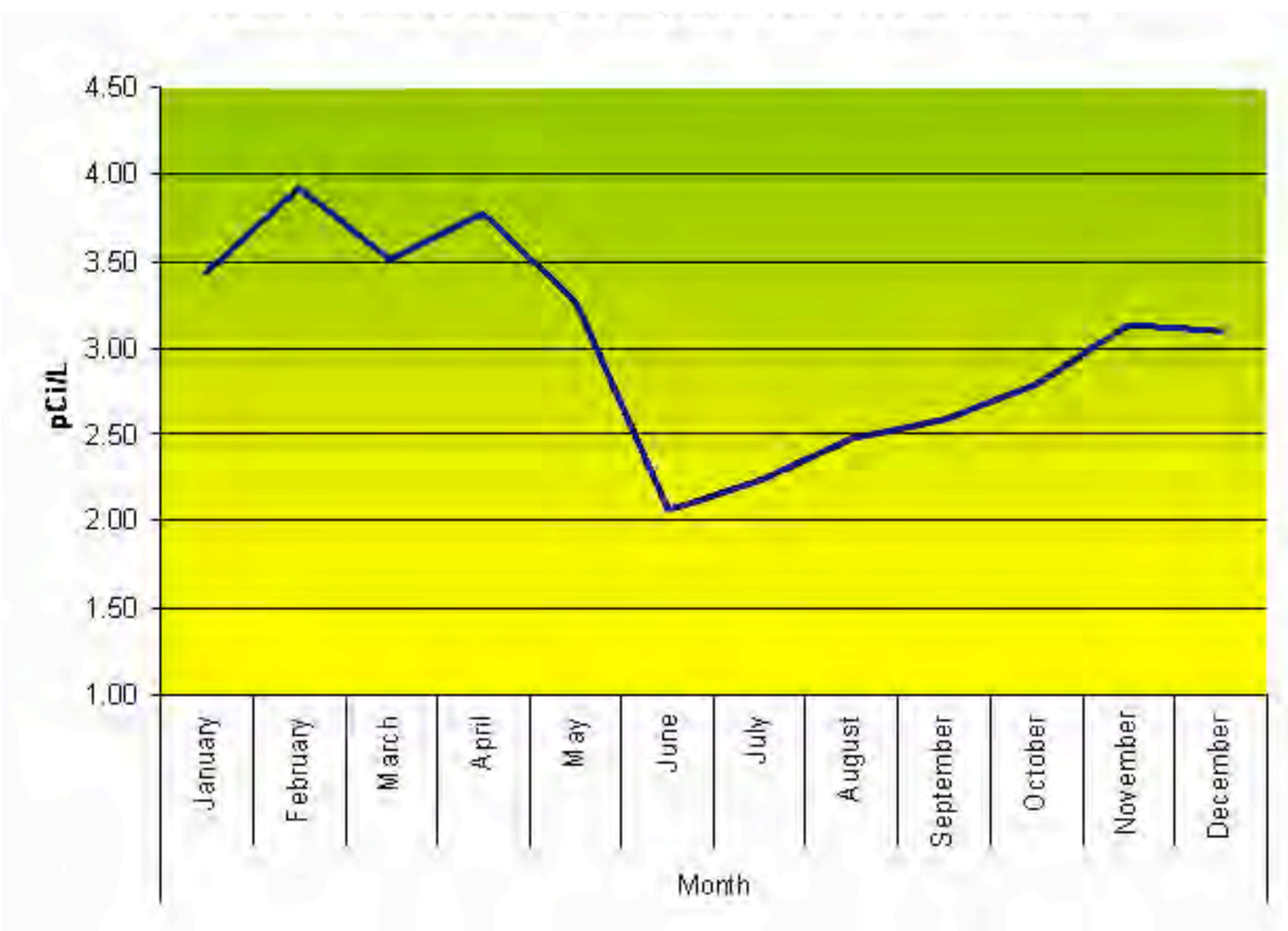
CLIMATE, GEOLOGY AND SNOW CAPPED MOUNTAINS

Soil gas movement is characterized by two mechanisms: plain diffusion and pressure differentials. During winter months, the presence of homes can extend pressure differentials in the soil away from foundations with the effect of radon gas being drawn up into the structure. This will, naturally, increase indoor radon levels within homes during winter months. The United States Geological Survey (USGS) asserts that "…the soil and climatic factors controlling soil-gas radon must be understood adequately…"

(Gunderson and Wanty, 1993; see also Zhang 2007) in order to predict the seasonal variation of soil and indoor radon values obtained from short-term sampling.

Utah receives less than 10 inches of precipitation annually and is the second driest state in the union (Precipitation, 2008). This lack of moisture contributes to the porous geology commonly found throughout Utah. During the winter months, water from melting snow packs seeps into the top-soil and will refreeze creating an ice cap in the top-soil. This ice cap decreases the flow of radon gas into the atmosphere and, combined with the frequent basement construction in Utah homes, increases indoor radon concentrations. During the summer months a similar effect can be seen in Utah homes as porous soils fill with water, lowering radon gas permeability (Figure 2).

Figure 2: Monthly averages of pCi/L levels in Utah homes



The effect of water frozen within the top-soil during winter months produces a more effective cap that retards radon flux to the atmosphere and potentially increases in residential soil-gas radon concentration results. Kovach (1945) found that the highest soil-gas radon concentrations of the year occur when the ground is frozen, an example of the increased radon gas trapping in the upper layers of the soil (see also Gunderson and Wanty, 1993). Consideration must also be given to cold air being heavier than warm air. This creates a cap on the soil that, along with frozen moisture, tends to inhibit radon gas from entering into the atmosphere. When combined with low barometric pressures associated with wintertime storms, ice caps hold more radon in the soil so it can then diffuse into structures.

Seasons Redefined

For the purposes of this study, we defined two seasons. First, "summertime" as months when the ground is not likely covered with snow (April through September) and second, "wintertime" as months when the ground is likely covered with snow (November through February). Indoor radon tests were conducted in January and February 2008 when Utah snow levels were significantly higher than in previous years. For 2008, reported snow levels were 118% and 171% of normal (Snowfall, 2008). By chance, 6-8 inches of snow fell on the day test kits were mailed to participants. This snowfall could be a factor in the accompanying results, though it should be noted that a snowcap effect was assumed during the wintertime.

MATERIALS AND METHODS

In 2004 the Utah Radon Program established a cooperative agreement with a local private health care provider, named Intermountain Health Care (IHC), to provide free indoor radon test kit coupons to parents of each newborn child. Approximately 6,815 test kits have been distributed with the intent to increase radon awareness and testing in Utah.

In November of 2007, the Utah Radon Program mailed 453 letters to potential participants (individuals who had previously tested their homes for indoor radon in the summertime). A follow-up reminder in mid-December of 2007 was also sent. 181 individuals responded affirmatively to the letter and agreed to participate in the study by conducting a second indoor radon test. Participants were mailed test kits during the week of 28 January 2008.

Of the initial 181 volunteers, 132 (73%) completed the wintertime follow-up test. Chen states "…this sample size can serve the survey purpose well" (Chen et al. 2008). Twelve of the original volunteers were sent quality control duplicates and asked to perform those tests side by side with identical opening and closing times. Ten of the twelve quality control duplicate tests came back within the quality control standards or coefficient of variation (COV) suggested by the EPA (EPA, 1993). [2]

Participation and Response

126 of the 132 wintertime produced acceptable indoor radon test results, e.g. sealed properly, correct start and end times listed, mailed within suggested timeframe, etc. These wintertime tests were used for statistical comparison with previous summertime levels.

Information was collected regarding in home placement of the test kits. As a result, 1 test kit result was removed due to the summertime test kit being hung from the ceiling while the wintertime test kit was placed on a folding chair.

RESULTS

Comparisons showed that 62% of the wintertime tests were higher than their summertime tests, 15% were lower and 23% were the same. ("Same" meaning within 14% relative difference, a range of the general level of precision attributed to activated charcoal adsorption tests (EPA, 1993)). 48 (38.1%) of

[2] Initial summertime indoor radon test kits were purchased from the provider "Air Chek, Inc." Follow-up wintertime indoor radon test kits were purchased from "Alpha Energy Laboratories." Both companies manufacture EPA approved activated charcoal adsorption tests.

the 126 wintertime tests results were above the 148 Bq m^{-3} threshold established by the EPA for mitigation, while 36 (19.9%) of the original 181 summertime tests were above the same 148 Bq m^{-3} threshold. Similarly, 41 of the 126 (32.54%) tests, when averaged according to EPA recommendations, were above the 148 Bq m^{-3} threshold (Figures 3 and 4). These results suggest that nearly 13% of all summertime indoor radon tests may result in a false negative reading, providing homeowners, REALTORS®, and relocation companies' with incorrect information. As noted by White (1994), "The chance of making the wrong mitigation decision increases as the mean of the two measurements approaches 148 Bq m^{-3} from either direction…." Performing a Student t-test (assuming equal variances) resulted in the two-tailed results being statistically significant at the 0.0001 level.

Figure 3: Seasonal averages of pCi/L levels in Utah homes

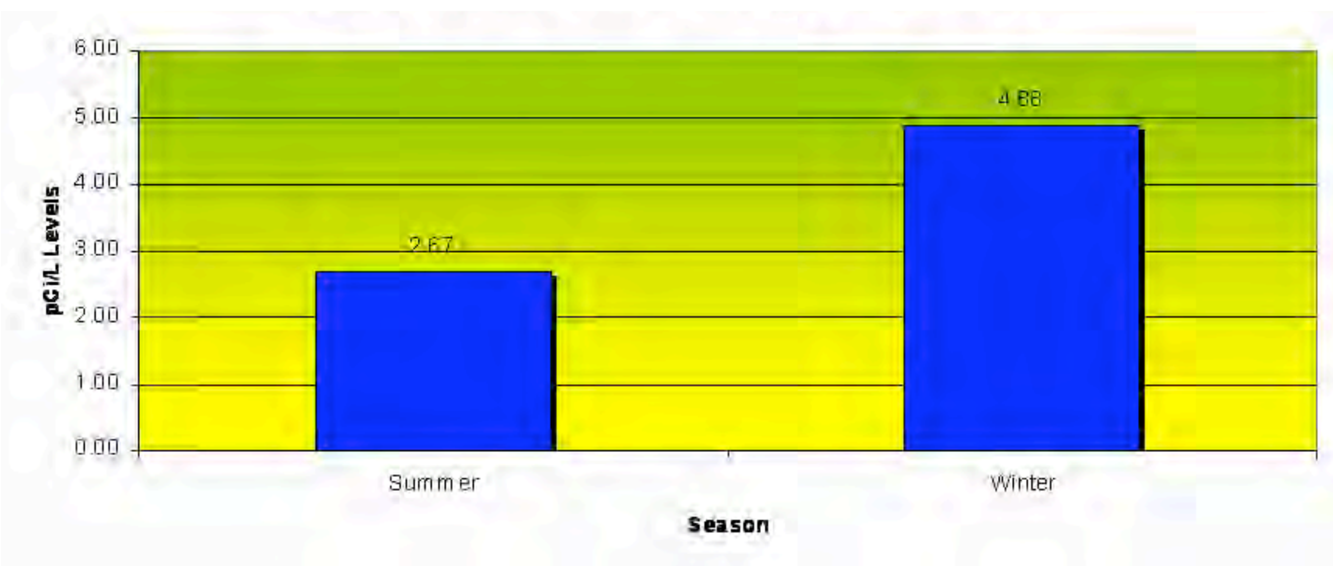
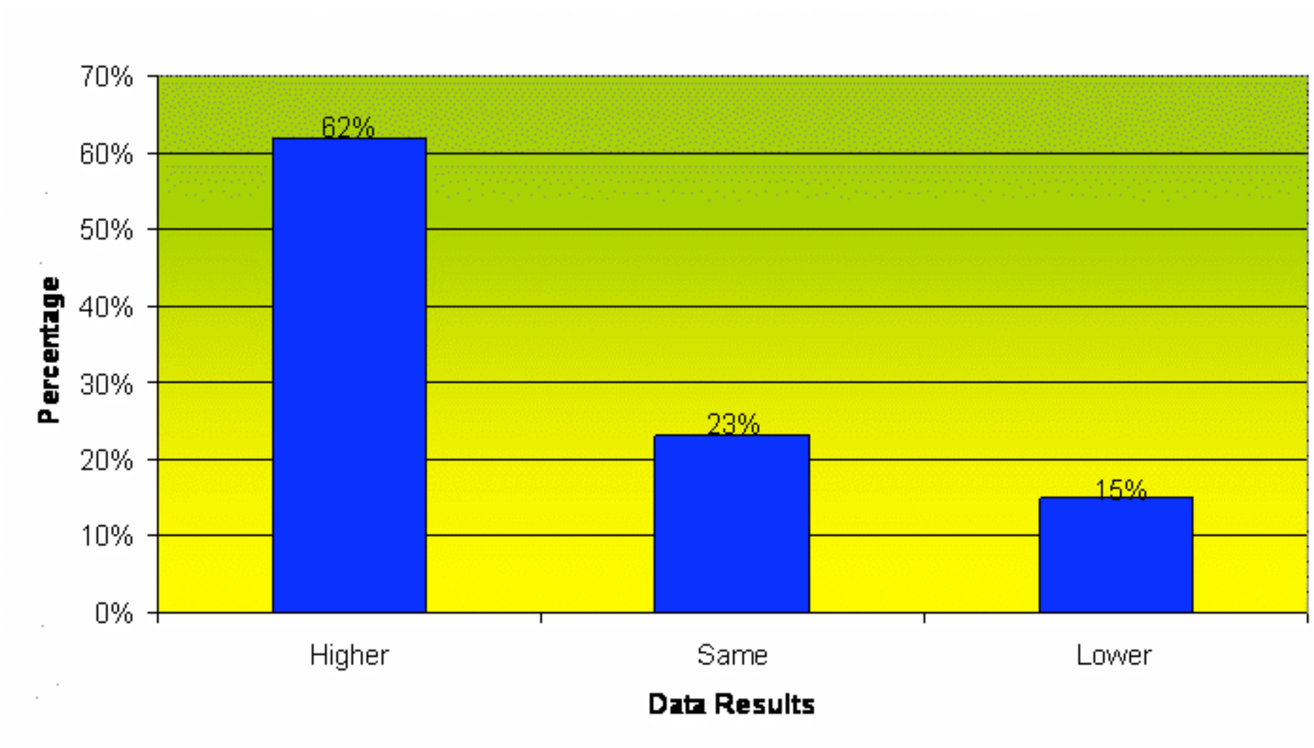


Figure 4: Comparisons between tests in different seasons



DISCUSSION

In Utah, wintertime indoor radon levels are expected to be higher based on the following factors: (1) ground surface soil moisture and snow cover, which inhibit radon gas movement into the atmosphere; (2) Pressure differentials between the interior of a home (due to heating the interior air) and the soil surrounding the home. Air pressure in homes tends to be lower than the soil surrounding them. This results in radon gas seeping through foundation openings into the home directly.

Our study suggests that indoor radon level testing during the summertime months should be followed by a wintertime test if the measured summertime radon values are above 3.5 pCi/L and that a wintertime test of 4.5 pCi/L should be retested in summertime to better understand the yearlong averages. A long term alpha-track detector placed inside the residence for one year would be the best solution.

CONCLUSIONS

Since real estate transactions occur more often in summertime months, the authors suggest conducting an additional indoor radon test in the wintertime in order to gather complete information on average radon concentrations in a particular home. Concerns associated with seasonal variations can be allayed by utilizing a long term test to measure yearlong averages in indoor radon gas concentrations of a particular home. In areas where the snow cover may increase indoor radon gas levels, the authors suggest an addendum to real estate transactions, escrowing the funds necessary to mitigate possible wintertime levels.

Acknowledgments

The author wishes to extend special thanks to Mario Bettolo of the Utah Division of Radiation Control. His substantive assistance in editing and organization cannot be quantified. Nevertheless, any errors are solely the authors' responsibility.

REFERENCES

Chen, J. Estimate of annual average radon concentrations in the normal living area from short-term tests, *Health Phys,* 85:740-744; 2003.

Chen, J, Tracy, BL, Zielinski, JM, and Moir, D. Determining the sample size required for a community radon survey. *Health Phys,* 94:362-365; 2008.

Climate data. Available at: http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html. Accessed . 19 March 2008.

Conference of Radiation Control Program Directors (CRCPD). *Radon Bulletin*, 3, pp. 2-3; 2007.

Cowley, G. and Kalb, C. (2005). The deadliest cancer, *Newsweek,* Available at: http://www.newsweek.com/id/56500. Accessed 12 March 2008.

Ford, ES and Eheman, CR. Radon retesting and mitigation behavior among the U.S. population, *Health Phys,* 72:611-614; 1997.

Gundersen, LCS and Wanty, RB. Field studies of radon in rocks, soils, and water—U.S. Geological Survey research on the geology, geophysics, and geochemistry of radon in rocks, soils, and water. 1993.

Kovach, EM. Meteorological Influences upon the Radon Content of Soil-gas, *Transactions, American Geophysical Union,* 26, 241-248; 1945.

McNees, JL and Roberts, SH. Summertime short-term negative radon tests need to be retested in winter, *Health Phys,* 93:74-77; 2007.

Precipitation data. Available at http://climvis.ncdc.noaa.gov/cgi-bin/cag3/state-map-display.pl. Accessed 19 March 2008.

Snowfall report data. Available at: http://www.crh.noaa.gov/product.php?site=NWS&issuedby=SLC&product=CLM&format=CI&version=4&glossary=0 . Accessed 26 March 2008.

Steck, DJ. Spatial and temporal indoor radon variations, *Health Phys,* 62:351-355; 1992.

U.S. Environmental Protection Agency. A citizen's guide to radon. Washington, DC: U.S. EPA; 402-K-00-006; 2004.

U.S. Environmental Protection Agency. Indoor radon and radon decay product measurement device protocols. Washington, D.C.; U.S. EPA; 520-402-R-92-004; 1992c.

U.S. Environmental Protection Agency. Protocols for radon and radon decay product measurements in homes. Washington, DC: U.S. EPA; 402-R-93-003; 1993.

White, SB. Making mitigation decisions based on short-term tests of ^{222}Rn, *Health Phys,* 67:180-182; 1994.

Zhang, Z, Smith, B, Steck, DJ, Guo, Q, and Field, W. Variation in yearly residential radon concentrations in the upper Midwest, *Health Phys,* 83:288-297; 2007.